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November 12, 2015

Stephanie Vaughn
17-mile LPRSA RI/FS Remedial Project Manager
U.S. Environmental Protection Agency, Region 2
290 Broadway
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***Via Electronic Delivery***

***Re: COPC Mapping White Paper – CPG Response — May 2007 Administrative Agreement and Order on Consent for Remedial Investigation/Feasibility Study – CERCLA Docket No. 02-2007-2009 (AOC)***

Dear Ms. Vaughn:

The Lower Passaic River Cooperating Parties Group (CPG) is delivering its response to USEPA Region 2's (Region 2) *"Review of the Cooperating Parties Group Approach to Mapping Contaminants of Potential Concern"* (White Paper) provided to the CPG on June 10, 2015. The CPG presents its detailed basis for developing the mapping in Section 2 and in Section 3, the CPG presents detailed technical responses to the analyses provided in the Region's White Paper.

In summary, Region 2's White Paper demonstrates an over-emphasis on the need for small-scale accuracy in target delineation to an extent that is inconsistent with an FS-level assessment and one that has not been required in previous Feasibility Studies (FS) by Region 2 or other USEPA Regions. The goal of the FS mapping is to reasonably represent concentration patterns to support remedial benefit evaluation with the available RI data. It is well known and accepted that RI data density is often insufficient to precisely delineate target areas during an FS, but this uncertainty is resolved during the design phase with the collection of a much denser dataset (e.g., RM 10.9 Characterization). Consequently, CPG's mapping adequately represents the variability in concentrations that are indicated by the data and which occur in coherent patterns as discussed in Section 2 of the CPG's White Paper response. Region 2's concern with small-scale accuracy blurs the lines between an FS-level evaluation which relies on a lower density RI data versus a remedial design with high-density data. The Region's position on the CPG's COPC mapping is inconsistent with both previous and current practice of USEPA and Responsible Parties conducting CERCLA RI/FSs at other sites including those in Region 2.

The CPG would like to meet with Region 2 and USEPA HQ representatives in December to discuss an appropriate and consistent approach to COPC Mapping for the 17-mile LPRSA RI/FS.

The CPG requests that Region 2 include this letter into the Administrative Records for both the 17-mile LPRSA Operable Unit and the 8-mile Proposed Plan of the Diamond Alkali Superfund Site. Please contact Bill Potter or me with any questions or comments.

Very truly yours,

***de maximis, inc.***

Robert H. Law, Ph.D
CPG Project Coordinator

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PAPER

# RESPONSE TO REGION 2 WHITE PAPER ON CONTAMINANT MAPPING

# LOWER PASSAIC RIVER STUDY AREA REMEDIAL INVESTIGATION/ FEASIBILITY STUDY

**Prepared for**

Lower Passaic River Cooperating Parties Group

**Prepared by**

Anchor QEA, LLC

(Woodcliff Lake, New Jersey; Boston, Massachusetts)

**November 2015**

# TABLE OF CONTENTS

## List of Tables



## List of Figures

## List of Appendices

## LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| μm | micrometer |
| 2,3,7,8-TCDD | 2,3,7,8-tetrachlorodibenzo-*p*-dioxin |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| CFT | contaminant fate and transport |
| COPC | chemical of potential concern |
| CPG | Cooperating Parties Group |
| Cs-137 | Cesium-137 |
| DQO | Data Quality Objective |
| FS | Feasibility Study |
| IDW | Inverse Distance Weighting |
| LPR | Lower Passaic River |
| LPRSA | Lower Passaic River Study Area |
| MPA | mass-per-area |
| ng/kg | nanogram per kilogram |
| OU | operable unit |
| PAH | polycyclic aromatic hydrocarbon |
| PCB | polychlorinated biphenyl |
| QAPP | Quality Assurance Project Plan |
| RAL | Remedial Action Level |
| RI | Remedial Investigation |
| RM | river mile |
| ROD | Record of Decision |
| SSP2 | Supplemental Sampling Program 2 |
| SWAC | surface-weighted average concentration |
| USEPA | U.S. Environmental Protection Agency |

# 1 INTRODUCTION

## 1.1 Overview of the White Paper and Major CPG Concerns

The Region 2 White Paper (dated June 10, 2015; hereafter White Paper) critiques the mapping used by the Cooperating Parties Group (CPG) to represent chemicals of potential concern (COPC) concentration patterns in the Lower Passaic River (LPR). In it, Region 2 expresses the view that the mapping approach is too inaccurate and biased to be used to support the contaminant fate and transport modeling and the delineation of areas meeting remedial action levels (RALs) set for Feasibility Study (FS) remedial alternatives. Region 2 believes that the mapping approach "can lead to overly optimistic assessments of the volume, schedule and cost of remediation required to achieve a needed risk reduction" (White Paper, page 2). Region 2 proposes that the use of the mapping be restricted to "estimation of site-wide average concentration, imputation of surface averages as model initial conditions within relatively large areas, and for developing weighted averages within relatively large subareas of the LPRSA [Lower Passaic River Study Area] that might be used to forecast remedial options" (White Paper, page 41).

The CPG strongly disagrees with Region 2's evaluation, and this document will demonstrate important flaws in the Region 2 critique of the CPG's mapping. Of particular concern is Region 2's evaluation does not consider the detailed presentation of findings laid out in the Draft 17-mile Remedial Investigation (RI) Report[1] (Anchor QEA et al. 2015), the biased nature of much of the technical analyses presented in the White Paper, and the selective use of RI data. Many of those analyses seem to be aimed at demonstrating a particular point rather than objectively assessing the CPG's mapping. In making several of these points, the White Paper implies a required standard of accuracy for the COPC mapping that is unprecedented and unattainable in an FS-level assessment of relative remedial benefit due to data density limitations. This required level of accuracy has not been applied in RI/FSs for other sites under Region 2's purview, and assumes an unintended purpose for the RI data that is inconsistent with the needs of an FS. Consequently, Region 2's critique over-emphasizes the importance of the uncertainty in target area delineation that would be addressed in remedial design using a higher density sampling dataset. Moreover, Region 2's

[1] The White Paper references only one appendix of the Draft 17-mile RI Report; the main report and its findings are not mentioned or cited in Region 2's discussion.

recommended alternative to use "weighted averages within relatively large subareas of the LPRSA that might be used to forecast remedial options" misrepresents COPC concentration patterns, is much less accurate than the CPG mapping, and would likely lead to technically unsound remedial alternatives. The White Paper has a questionable underlying premise: if the mapping does not meet some arbitrarily high standard for accuracy, it should be replaced by an alternative approach that is demonstrably less accurate.

The CPG stands behind its mapping approach as an appropriate characterization of the contaminant distribution suitable for identifying and modeling targeted remedy alternatives for the FS. The remainder of this section describes the goals of mapping within an RI/FS and the consistency of the CPG mapping with that performed for other sites. Section 2 reviews the scientific basis for the CPG mapping, which derives from a conceptual model that was developed from extensive review of LPR contamination patterns. Section 3 explains the CPG's observations and concerns with the technical arguments raised by Region 2:

- Surface-weighted Average Concentration Reduction Achieved by Targeted Remediation (Section 3.1)
- Testing Target Delineation in the River Mile 10.9 Area (Section 3.2)
- Mapping Changes Between 2013 and 2015 (Section 3.3)
- Region 2's Use of the SSP2 Data to Test Earlier Mapping (Section 3.4)
- Region 2's Statistical Simulation to Evaluate Targeted Remedy Delineation (Section 3.5)
- Region 2's Recommendation to Use Large-scale Averages (Section 3.6)

Lastly, Section 4 provides a summary of the major conclusions.

## 1.2 Contaminant Mapping is a Normal Part of the RI/FS Process

The crafting of remedial alternatives for contaminated sediments requires that concentration patterns be mapped over the site. The picture of the nature and extent of contamination that results from the mapping has been the basis for crafting remedial alternatives since the inception of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Textbooks have been written on the subject, and the U.S. Environmental Protection Agency (USEPA) website is replete with maps for sites under its purview and FS documents in which remedial alternatives are crafted by drawing boundaries on maps at particular concentration values.  Much less common are examples where point-by-point mapping has been replaced by averages over large areas, as Region 2 has proposed here.

The approximate nature of concentration maps generated on RI-level data, which is common knowledge, does not preclude their application and that approximate nature is the reason remedy design rarely relies on FS-level mapping.  That said, the goal of FS-level mapping is to provide a reasonable representation of concentration patterns.  A reasonable representation is all that is needed within the context of the many uncertainties inherent at the FS stage that motivated USEPA to set a goal of cost accuracy of +50%/-30% (USEPA 1988).

## 1.3 Contaminant Mapping at Other Sites Demonstrates the Validity of the CPG Mapping Approach

RIs do not collect sediment samples at the density typically needed for remedial design.  This is so because such sampling can be extraordinarily expensive, time-consuming, and wasteful since it would include many samples in areas where remediation is not needed.  It also may need to be repeated in remedial design if a number of years pass between the RI and design and/or events occur that alter concentrations from those measured in the RI.

Table 1-1 provides an overview of the sampling densities and interpolation approaches used at four different Superfund sites from across the country (Portland Harbor, Buffalo River, Upper Hudson River, and Lower Fox River) and representing three different USEPA Regions (Regions 2, 5, and 10), in addition to the LPR.  As indicated in Table 1-1, RI sampling at sites on the scale of the LPR typically occurs at densities less than one sample per acre, with the exception of the Buffalo River.  This density has proven to be sufficient to identify concentration patterns, particularly when combined with other information pertinent to those patterns (e.g., contaminant release locations and history, flow patterns and velocities, sediment type, and geomorphology and sedimentation rate).  This comprehensive knowledge allows reasonable delineation of the site and physically-based constraints on mapping.

At each of the sites listed in Table 1-1, an interpolation approach was employed to map concentrations, not large-scale averaging as proposed by Region 2 for the LPR. A brief overview of the concentration mapping at these sites is provided below.

Portland Harbor is a superfund site in Portland, Oregon, that is contaminated with various COPCs including polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbon (PAHs), dioxin, and pesticides. The RI/FS mapping used Natural Neighbors to interpolate contaminant concentrations.

The Buffalo River is located in western New York State and contaminants include PAHs, PCBs, lead, and mercury. Contaminant concentrations were interpolated using Inverse Distance Weighting (IDW) in the RI/FS mapping.

The Upper Hudson River and Lower Fox River offer good examples of the adequacy of mapping of RI scale sampling results as a reasonable representation of conditions established by high density remedial design sampling. In fact, Region 2's sediment sampling and target delineation approach for the Hudson River FS is nearly identical to what the CPG has done for the LPR. As stated in Appendix B of that FS Report, "[t]arget areas in the Thompson Island Pool were delineated by primarily using 1984 NYSDEC results interpreted via a polygonal declustering analysis (Thiessen polygons) in conjunction with the 1992 USEPA side-scan sonar survey results" (USEPA 2000). More detail on both of these sites is provided in the following subsections.

### *1.3.1 Upper Hudson River*

The Upper Hudson River Superfund Site is a 40-mile stretch of river in Upstate New York being remediated for PCB-contaminated sediments. Region 2's delineation of the remedial footprint used for the evaluation of alternatives in the 2000 FS was based on PCB sampling and sediment texture information that were collected in 1977, 1984, 1991, 1992, 1994, and 1998. While multiple datasets existed, the spatial coverage of these data varied over the 40-mile site and the data extent was limited in some areas. The cores per acre used for the Upper Hudson River FS is similar to that of the current LPRSA RI dataset collected between 2005 and 2013 (Table 1-1). As with the Upper Hudson River, spatial coverage within the

LPRSA varies, with less data density in areas where sediment concentrations are uniformly low and COPC patterns have been inferred.

For the upper-most reach of the Upper Hudson River, the target footprint was established using maps derived from Thiessen polygons and information on surface sediment type. Professional judgment was also used to cluster targeted areas together, and the final footprint was checked against other data, where available (USEPA 2000, Appendix B). In portions of the river below the upper-most reach, where the sampling density was even lower, the mapping technique relied more heavily on sediment texture information. The approximate nature of the mapping was acknowledged by Region 2; subsequent documents noted that remedial delineation would be fully defined using the pre-design sampling that would occur after the issuance of the Record of Decision (ROD). As in the upper-most reach of the Hudson River, Thiessen polygons and sediment type (silt areas) were used in the Passaic mapping above river mile (RM) 7.8.

Pre-design data collected after the ROD show that the FS characterization of the selected remedy worked well overall. The FS characterized the selected remedy as targeting 2.65 million cubic yards of sediment over 493 acres (USEPA 2000). The final remedy developed after design included 1.8 million cubic yards of sediment over 491 acres (QEA 2007). Not surprisingly, differences exist, but they do not invalidate the basis for choosing the remedy or greatly alter the benefits the remedy was predicted to achieve. An example where the FS and final delineations compare well is near RM 186 where there was a large deposit of fine sediments (Figure 1-1). An example where the design data uncovered something not evident in the earlier mapping is shown in Figure 1-2. The FS delineation near RM 192 targeted only the shoreline areas (Figure 1-2, left panel). However, subsequent data collection during pre-design indicated almost bank-to-bank dredging in this area (Figure 1-2, right panel).

Examples of similarities and differences between the FS footprint and the final design for the Upper Hudson River can be found throughout the 40 miles of river. The differences merely show how refined information collected during the pre-design phase can improve the delineation. Region 2 has stood behind the predictions made using the mapping in the FS and reported in the first 5-year review of the Upper Hudson River remediation that the FS approach predicted a reduction in surface sediment concentrations for the entire river that was close to that calculated using the pre-design data and final design footprint (Garvey and Atmadja 2012).

### 1.3.2 Lower Fox River

The Lower Fox River is a Superfund site near Green Bay, Wisconsin, with PCBs driving the cleanup of 39 miles of river and South Green Bay, where the river meets the bay. The data density used for establishing the nature and extent of the PCB contamination for the Lower Fox River FS was similar to the LPR when comparing number of locations by RM, but slightly less when looking at the cores per acre metric (Table 1-1). A peer review commissioned by USEPA Region 5 concluded that the data coverage used for the Lower Fox River FS was adequate for the purposes of determining the nature and extent of the contamination and selecting a remedy (Weston 1999). After the FS, extensive pre-design sampling was implemented to complete the design of the final remedial footprints (Table 1-1).

In operable unit (OU) 4 of the Lower Fox River, the target footprint was established using maps derived from an IDW interpolation. Concentrations greater than 1,000 parts per billion were targeted (Figure 1-3, left panel). Like the draft 17 mile Passaic River RI, the Lower Fox River used an interpolation (rather than large-scale averages).

As with the Hudson River, while there are differences between the target areas delineated during the FS compared to the final footprints in the design, the FS mapping approach is representative and provided a good estimate of the areas that should be considered for remediation. For example, in OU4, the design sampling reduced the targeted areas from those identified in the FS but found that the FS had identified nearly all the areas that were ultimately targeted (Figure 1-3).

# 2 THE CPG MAPPING DERIVES FROM A SCIENTIFIC UNDERSTANDING OF RIVER BOTTOM EVOLUTION

The mapping, in particular the delineation of the river based on erosion/deposition patterns and sediment type, derives from the science-based expectation that surficial sediment COPC concentrations are related to the history of erosion and deposition and the nature of the deposited sediments. These factors control to a great extent the sources and sinks of COPCs to the sediment and the history of surficial sediment concentrations. This concept is thoroughly examined in the Draft 17-mile RI Report, which shows that the evolution of sediment deposits has produced logical patterns of surficial sediment COPC concentrations (Anchor QEA et al. 2015).

Consequently, the CPG mapping defines distinct "groups" within which concentrations are interpolated. The eastern shoal, western shoal, and channel are grouped separately throughout the river, as are silt areas above RM 7.8. The channel is sub-divided into additional groups between RMs 2.3 and 7.8, based on depositional history inferred from changes in bathymetry. Interpolation within each group is performed via Thiessen polygons. A complete description of the group definitions and interpolations is found in Appendix J of the Draft 17-mile RI Report (Anchor QEA et al. 2015). This is conceptually similar to the geomorphic grouping approach by Region 2 "to help understand the general lateral and longitudinal features in the river. Identification of these features can help to better understand transport trends and more effectively design remediation" (SEI and HQI 2011)

The White Paper questions the scientific underpinnings of the CPG mapping based mainly on a single issue pertinent to one portion of the mapping: the partitioning of the river channel between RMs 2.3 and 7.8 into groups based on bathymetric change (i.e., long-term net erosion or net deposition). It posits that the groups are simply based on surficial sediment 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) concentration patterns and lack a scientific rationale, emphasizing the selection of the threshold values of bathymetric change used to define the boundaries between groups. The CPG disagrees with the emphasis placed by Region 2 on the uncertainty in the definition of the threshold values, which has little impact on the map and the identification of remedial alternatives, and the subsequent dismissal of the scientific basis for partitioning the river using the conceptual model developed in the Draft 17-mile RI Report. The text that follows reviews the scientific basis underlying the delineation throughout the LPR, which allows for a reasonable representation of contaminant patterns suitable for the FS evaluations.

The primary COPC for the LPRSA is 2,3,7,8-TCDD. It first entered the river in the late 1940s and early 1950s. A logical expectation based on the geomorphological characteristics of the LPR is that 2,3,7,8-TCDD will be present in low concentrations where sediments have not been deposited since this time. Where sediments have been deposited, concentrations should reflect the nature of the depositing sediments, the amount and timing of that deposition, and the location in the river relative to source locations. Where deposition stopped prior to the reduction in contaminant loading to the river in the late 1960s, relatively high concentrations should exist if fine sediments were deposited. Where deposition has continued to the recent past, concentrations should reflect the recent concentrations on suspended solids.

## 2.1 Conceptual Model Based on River Bed Evolution

The LPR is a classical partially-mixed coastal plain estuary of relatively shallow depth, gently sloping bottom, and expanding cross-section from Dundee Dam to Newark Bay. It contains meanders reflective of its ancestral river channel. Its sediment dynamics, sediment transport, and geomorphological features reflect fluvial and estuarine processes influenced by navigational dredging and infilling after maintenance of the navigational channel ceased.

The evolution and nature of the sediment bed of the LPR are the result of well-understood fluvial and geomorphological processes typical of a tidal-dominated system (see Section 3 of the Draft 17-mile RI Report [Anchor QEA et al. 2015] and Region 2's LPR System Understanding of Sediment Transport [SEI and HQI 2011]). The surface sediment characteristics of the LPR reflect this theory, with fine sediments along the bends of the fluvial estuary (RMs 8 to 14) and throughout the upper estuary (RMs 0 to 8) and coarser sediments in the center of the fluvial estuary and at the tidal river (see Figure 3-12 of the Draft 17-mile RI Report [Anchor QEA et al. 2015]).

The evolution has been affected by historical navigational dredging (see Section 1.2 of the Draft 17-mile RI Report for details [Anchor QEA et al. 2015]):

- The lower 1.9 miles were last maintained in 1983
- Most of the channel upstream of RM 8.3 was last dredged in the 1970s
- The channel between RMs 1.9 and 8.3 was last maintained before 1950

Maintenance history has impacted depositional history and sediment nature in the channel and adjacent shoal, which in turn has impacted the spatial distribution of contamination in the river.

Sedimentation rates estimated from Cesium-137 (Cs-137) concentrations (see Section 3.6 of the Draft 17-mile RI Report for more details of the analysis [Anchor QEA et al. 2015]) indicate the following:

- The highest rates of sedimentation occurred in the lower 7 miles and within the navigation channel, reflecting infilling following cessation of channel maintenance.
- Above RM 7, where there was more spatially/temporally sporadic historical dredging and a shallower channel, net sedimentation rates have been notably lower.
- The deposition that formed the mudflats upstream of RM 7 has decreased in a manner reflecting upstream to downstream and shore to channel evolution, with the older portion having reached quasi-equilibrium circa 1960s.

This understanding of the bed evolution leads to the following conceptual model of contaminant distribution in surficial sediments:

- Concentrations should be low in areas routinely subject to high velocities where sediments have not accumulated (though there may be some deposited sediments intermixed with coarse material).
- Concentrations should reflect contemporary levels on suspended solids in areas continuing to undergo infilling.
- Concentrations should be most variable in areas that were historically depositional, but are not so under contemporary conditions. The upstream portions of point bars exhibit this characteristic, and 1960s-era sediment with high contamination have been observed here.

The contamination patterns within the LPR were thoroughly studied to test the conceptual model and to support a mapping strategy. As detailed in the Draft 17-mile RI Report and summarized below, the patterns generally conform to the conceptual model. Thus, the conceptual model forms a strong basis for mapping and was used to guide the CPG mapping. The CPG stands behind its mapping approach as an appropriate means to characterize the contaminant distribution for the purpose of identifying and modeling targeted remedy alternatives for the FS.

## 2.2 The Conceptual Model Was Tested and Refined

### *2.2.1 Point Bar Evolution Was Studied*

As discussed in Section 3.6 of the Draft 17-mile RI Report, the Morphologic Features section of Region 2's System Understanding document (SEI and HQI 2011), and in Section 2.1 above, the LPR contains meanders reflective of its ancestral river channel. The point bars associated with the LPR's meanders formed over an extended period, similar to point bars on other meandering rivers (Dalrymple and Choi 2006; Dalrymple and Rhodes 1995). That is, the bars developed from the shore outward (Figure 2-1; Fryirs and Brierley 2013). The result of this process is layered deposits of sediment on the inside bends of the river, consisting of a mix of coarse and fine material, with the finer material found near the surface and in the downstream portion of the deposit (Fryirs and Brierley 2013). The point bars form such that the general model for the current condition is as follows:

- The nearshore and upstream portion attained quasi-equilibrium at some time in the past, and the surface sediments were laid down some time ago.
- The channel side and downstream portion are still subject to infilling.

The shoal at RM 10.9 provides a particularly important example of such a point bar because high density sediment data are available here from the extensive remedial design investigation that was conducted to support an early action remediation of this area in 2013 (Figure 2-2). These design-level data allowed the CPG conceptual model to be tested more extensively than at other locations where data density is lower. Consequently, the RM 10.9 area is revisited several times in this document to illustrate the CPG conceptual model (below) and to respond to Region 2's critique of the CPG mapping (Section 3). It is anticipated that data of a similar density would be available in the future as part of the remedial design investigation.

Historical bathymetry along a transect at RM 10.9 (Figure 2-3) confirms the general expectations described above. For approximately 100 feet from the right bank, infilling stopped in the mid-1970s or earlier. Further offshore infilling continued to the most recent survey in 2004, with the point bar expanding along the eastern bank following the dredging event in 1976.

Surficial sediment 2,3,7,8-TCDD concentrations, the depth of peak concentrations, and the depth of contaminated sediments (using a 50 nanograms per kilogram [ng/kg] threshold) in the RM 10.9 shoal follow logically from this pattern of evolution, as is evident in Figure 2-4.[2] Groupings are visually evident throughout the shoal: along the shore, upstream to downstream, and laterally. To illustrate the coherence within an area and the difference between areas within the same shoal or geomorphic unit, two areas approximately 500 feet long are compared in Figure 2-4. The purple hatched area is in the upper portion of the interior of the shoal where infilling stopped (peaks concentrations tend to be at the surface). This purple hatched area has high surface concentrations (middle panel) and relatively shallow depths of contamination (left panel), whereas the blue-green hatched area downstream has much lower concentrations and greater infilling (peak concentrations tend to be buried and the depths of contamination are relatively high). The different distributions of data in these two areas can be seen on three plots in the right panel.

The organized spatial patterns are clearly evident in three-dimensional maps in areas of higher density data, such as one at RM 10.9 (Figure 2-5a to 2-5c) and one at RM 7.5 (Figure 2-6). Concentrations follow the bathymetry, which reflects the evolution of the deposit.

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[2] In Figure 2-4, complete cores are those described in Section 1.2 of Appendix I in the Draft 17-mile RI Report. On the contaminated sediment depth panel, low concentration cores have 2,3,7,8-TCDD concentrations less than 50 ng/kg in all slices. Deep and shallow contaminated sediment depth are classified by how deep below the peak concentration the core segments exceed 50 ng/kg. In shallow cores, the above occurs within 5 feet of the surface. In deep cores this occurs more than 5 feet below the surface. Deep cores also include cores (of any length) that exceed 50 ng/kg at all sample depths, or never decrease to less than 50 ng/kg at depths below the peak concentration.

### 2.2.2 Contaminant Patterns Along Transects Were Studied

Lateral contamination patterns confirm the conceptual model presented above. A transect across a point bar at RM 10.1 (Figure 2-7a) illustrates how concentrations decrease when moving toward the channel, reflecting the varying state of evolution. The 2,3,7,8-TCDD concentrations in the sample closest to the bank are in excess of 10,000 ng/kg, consistent with older sediments having not been buried, while concentrations in the channel are less than 250 ng/kg, reflecting the coarse nature of the sediments. A similar trend is observed on a transect at RM 9.3 (Figure 2-7b); while concentrations outside the channel are greater than 1,000 ng/kg, concentrations within the channel are less than 250 ng/kg.

A transect at RM 7.3 (Figure 2-7c) shows an elevated concentration in the shallow shoals on the eastern bank transitioning to low concentrations towards the center of the river. A high concentration is again measured on the steep western slope where the sediment type becomes more sandy in nature. This high surface concentration is also higher than any at-depth concentration in the local sediment column, suggesting circa 1960s sediments and behavior analogous to that found in the RM 10.9 point bar. Similarly, high concentrations are observed on the eastern and western slopes at RM 7, but the channel itself contains low concentrations (Figure 2-7d).

### 2.2.3 General Patterns of Concentration Across Geomorphic Features Between River Miles 7.8 and 15 Were Examined

As shown for 2,3,7,8-TCDD in Figure 2-8, concentrations vary among sediment types in the expected manner. They are lowest in sands and coarser material (i.e., mixtures of sand, gravel, and rock) with less than 20% fines and highest in silt and coarser material with a high silt content (greater than 20% fines). The median concentration in the former is approximately 20 ng/kg, whereas it is approximately 400 ng/kg in the latter. Approximately 40% of the samples in the fine sediments have concentrations greater than 500 ng/kg, whereas none of the sand samples and only one of the coarser material with less than 20% fines exceed this concentration. Samples from areas of a sand-silt mixture are also low and similar to the sand and coarser material with less than 20% fines samples, with only approximately 15% having concentrations greater than 500 ng/kg.

The concentration characteristics of the sediment types support the CPG mapping approach of separating the silt areas upstream of RM 7.8 from other areas. The finding of high concentrations in coarser sediments containing greater than 20% fines[3] means that these high concentrations may not be representative of the overall coarser sediment area and may be the result of a sampling bias. A bias may exist because coring the coarser sediments is difficult and repeated efforts to obtain a useable core likely leads to finding and sampling small pockets of finer sediments. For this reason, the Supplemental Sampling Program 2 (SSP2) targeted areas around high concentration samples in coarser sediments in an effort to refine the area over which the high concentrations are mapped.

### *2.2.4 Concentration Patterns in the River Miles 2.4 to 6.8 Channel Were Compared to Estimates of Net Deposition/Erosion*

The navigation channel between RMs 2.4 and 6.8 has been surveyed for bathymetry numerous times since 1949. Changes in bathymetry between surveys provide an estimate of net deposition or net erosion rates at locations where cores were collected for contaminant analysis. These estimates were used to test the conceptual model and to provide a means to partition this portion of the channel[4] for purposes of mapping. Figures 2-9 and 2-10 show surface 2,3,7,8-TCDD concentration and mass-per-area (MPA) in the channel, respectively, as a function of the amount of historical deposition (black markers). Negative x-axis values on these plots represent erosion, and the historical bathymetric changes are here referenced to the 2011 bathymetric survey. Changes between 1949 or 1966 and 2011 were used for partitioning the channel. The bathymetric change since 1949 reflects sediment accumulation since approximately the start of 2,3,7,8-TCDD discharges to the LPR, and the bathymetric change since 1966 reflects sediment bed evolution following the initial accumulation of 2,3,7,8-TCDD-laden sediments. Figures 2-9 and 2-10 also include shoal samples within the extents of these bathymetric surveys (green markers), for additional evaluation of the conceptual model.

[3] The fraction of fine sediments is calculated as the mass fraction of sediment passing through a 63 micrometer (μm) sieve, or a 75 μm sieve if 63 μm sieve data are unavailable.
[4] In this paragraph, channel refers to the part of the river that is outside the shoal as opposed to the official boundaries of the former navigation channel. The 1949 bathymetry dataset consists of bathymetry data collected in both 1949 (RM 2.4 to 5) and 1950 (RM 5 to 6.8).

As expected, the top panels of these figures show that locations where no sediment accumulated between 1949 and 2011 (left of the dotted line representing the bathymetry change threshold) have mainly low surface 2,3,7,8-TCDD concentration and low MPA. Among locations that accumulated sediments since 1949 (right of the threshold), surface 2,3,7,8-TCDD concentrations tend to decrease and MPA tends to increase with increasing deposition, emphasizing the importance of burial as a mechanism reducing surface contamination but increasing contaminant trapping.

The bottom panels of these figures only include locations where sediment accumulated since 1949 (the circles of the top panels) and look at patterns in relation to net deposition since 1966. As expected, the highest surface concentrations generally occurred at locations that experienced erosion or less than 6 inches of deposition since 1966, thereby leaving deposited 2,3,7,8-TCDD at or close to the surface. Locations that experienced greater deposition tend to have concentrations in a relatively narrow range (bottom panel of Figure 2-9)—these concentrations are mostly consistent with those measured by Region 2 on recently deposited sediment (LBG et al. 2014) and measured on suspended sediments in RI sampling events (see Section 6.2 of the Draft 17-mile RI Report [Anchor QEA et al. 2015])—again the logical result of deposition of cleaner contemporary solids. The MPAs in these locations are comparable to those in the erosional areas, confirming that contaminated sediments did settle in these locations but have been buried under cleaner solids.

The above concepts were used to partition the channel between RMs 2.3 and 7.8.[5] The White Paper criticizes setting the threshold for areas with no sediment accumulation at a bathymetric change of -0.4 feet rather than 0 feet. That was done to avoid having two samples with elevated concentration and bathymetric change between 0 and -0.4 feet located in a region that otherwise has low concentrations. Ensuring that those samples were excluded is supported by the fact that these locations did experience net deposition between 1966 and the year of sampling (as opposed to 2011) and have much higher MPA than the other samples with bathy change less than 0 feet. In any event, setting the threshold at 0 rather than -0.4 feet would have little impact on the mapping. Such a change affects 5 of the

[5] As discussed in Appendix J of the Draft 17-mile RI Report (Anchor QEA et al. 2015), the 1966 bathymetry survey extends from RM 2.3 to 7.8 and is used to expand the bathymetry-based groupings beyond the RM 2.4 to 6.8 extent of 1949 the bathymetry dataset.

940 acres over which contaminant concentrations are mapped. Moreover, the bathymetric threshold only defines the boundaries between the groups, and because each sample is interpolated spatially, minor shifts in the groups have a limited impact on the concentration field and the remedial benefit calculation. In general, Region 2's concern over exceptions to the trends discussed above and the impacts on mapping is puzzling given that individual sample influence is limited by interpolation within groups (as opposed to large-scale averaging). The uncertainty of the group delineations does not invalidate the conceptual reasoning underlying their definition.

# 3 RESPONSE TO POINTS RAISED IN THE WHITE PAPER

## 3.1 Surface-weighted Average Concentration Reduction Achieved by Targeted Remediation

### *3.1.1 Region 2's Position*

Section 2 of the Region 2 White Paper considers the relationship between surface-weighted average concentration (SWAC) reduction and remediated area, which it expresses mathematically in terms of the ratio between concentrations in remediated and un-remediated areas (Figures 1 and 2 of the White Paper). On the basis of this relationship, Region 2 posits:

> *The relationship described in Figure 2 is important because these generally applicable mathematical relationships impose performance constraints on remedial implementation, without which the forecast reduction in SWAC (i.e. risk reduction) might not be attained in practice. The CPG's proposed remedial alternative would require a relatively high target to non-target concentration ratio of 26 to 1 to be successful, implying that delineation accuracy must be more highly resolved than if a higher percentage area were to be remediated. Conversely, less highly resolved mapping accuracy would be required for a remedy based on a concentration ratio of 2 to 1. The ability to accurately predict and reach a successful outcome would ultimately be determined by the accuracy of the COPC mapping procedure…*
>
> *The Mapping Approach is used to develop a forecast of the effectiveness of a RAL in achieving a post-remedial SWAC. The accuracy of the forecast requires unbiased estimation of the average concentration within the two delineated areas—target and non-target. Misclassification of sediments relative to the RAL, i.e., either understatement of the non-target average or overstatement of the target average, would cause overstatement of relative reduction in SWAC. While these potential biases are not unique to the approach utilized by the CPG for the LPRSA, the errors in this case may be unusually large due to assumed sharp divisions between target and non-target areas due to potential over fitting, and because of demanding delineation*

*accuracy requirements associated with the relatively small proposed remedial footprint.*

### 3.1.2 Region 2 Mischaracterizes the Relationship Between 2,3,7,8-TCDD Concentrations in and out of Target Areas

The curves shown in Figure 2 of the Region 2 White Paper are of little practical value and are used to incorrectly imply that the ratio of the average concentration in remediated to un-remediated areas is 26:1 throughout the river. That is not the case; approximately half of the target areas have ratios less than 10:1.

The CPG's Targeted Remedy delineation yields an overall ratio of 26:1 due to the influence of a relatively small subset of target areas. This influence is evident in Figure 3-1, whose top panel shows how the average target area concentration varies as targets are successively included in order of ascending concentration. The corresponding increase in the ratio of the average concentration in target and non-target areas is shown in the bottom panel[6]. Considering half of the target areas yields a target to non-target average concentration ratio of approximately 5, whereas including 85% of target areas brings that ratio to 10. The remaining 15% of target areas (roughly 20 acres) have an average concentration ten times higher than the average of the other 85%, and drive the overall target to non-target ratio from approximately 10 to 23 (it does not reach Region 2's ratio of 26:1 for the entire LPR because this analysis is restricted to RMs 0 to 14.7 so as to match the longitudinal extent of the CPG Targeted Remedy). Thus, delineating the targeted remedy does not require distinguishing areas throughout the river that are 26 times more elevated than the average of non-target areas as Region 2's implies; in most cases the difference between target and non-target areas is considerably lower.

The presence of a small area with extremely high concentrations is a distinctive characteristic of the LPR and reflects the fact that some areas of fine sediment deposits

[6] To illustrate the impact of target areas on the concentration ratio in the bottom panel of Figure 3-1, the average concentration in non-target areas is defined for the full remedial footprint (dashed line in top panel), and does not vary as a function of the target areas included in the calculation (i.e., the horizontal axis in both panels).

stopped their development during the period of active releases in the 1960s and the high concentrations deposited in that period were never buried. This distinctive characteristic is evident when the 2,3,7,8-TCDD concentration distribution in LPR surface sediments (RMs 0 to 15) is compared to the PCB distributions[7] in the Upper Hudson River (Thompson Island Pool) and the Lower Fox River (OU4), on a median-normalized basis (Figure 3-2). The distribution is broader in the LPR. Concentrations of 100 times the median or more are more prevalent relative to the two other sites. Consequently, the difference between the mean and median concentrations is greater in the LPR dataset (factor of 6.9) than for the other two sites (factors of 3.4 and 2.1 for the Upper Hudson River and Lower Fox River, respectively), and this characteristic suggests a potentially greater benefit from a targeted remediation. This is illustrated conceptually in Figure 3-3, which shows an approximation of potential remedial benefit by evaluating the change in the mean concentration as samples are successively zeroed out in descending order of concentration. These curves are conceptual only in that the concentrations are not interpolated to account for the spatial distribution and spatial weighting of the samples, and moreover, the curve implicitly assume the presence of coherent patterns such that high concentrations can practically be targeted. These simplifications notwithstanding, the steeper decline in the LPR average concentration as the highest concentrations are "remediated" suggests a greater potential for risk reduction due to targeted remediation at the LPR relative to the other sites. Areas of high and low concentration within the LPR occur in coherent patterns consistent with physical processes (Section 2), and it is therefore important that the LPR mapping adequately capture the variability to support realistic assessment of remedial benefit.

Although the CPG agrees with Region 2's position that accurately representing "the effectiveness of a RAL in achieving a post-remedial SWAC" requires "unbiased estimation of the average concentration within the two delineated areas—target and non-target," Region 2 over-emphasizes the need for small-scale accuracy in target delineation to an extent that is not appropriate for an FS-level assessment. As noted in Section 1.2, the goal of the FS mapping is to reasonably represent concentration patterns to support remedial benefit

[7] PCBs are shown for the Upper Hudson River and the Lower Fox River because they are the primary contaminant of concern and the basis for remedial design at these sites. The data shown on the Lower Fox River are total PCB concentrations for segments with a start depth of zero (typically 0 to 6 inches). The data shown on the Upper Hudson River are the maximum tri+ PCB concentrations in the top 12 inches.

evaluation with the available data. The data density is insufficient to precisely delineate target areas during an FS, but this uncertainty will be resolved during the design phase with the collection of a much denser dataset (e.g., such as the one at RM 10.9). Consequently, the CPG mapping aims to adequately represent the variability in concentrations that are indicated by the data and which occur in coherent patterns as discussed in Section 2. Region 2's concern with small-scale accuracy inappropriately blurs the lines between an FS-level evaluation and a remedial design, and unfortunately this mindset pervades the critique of the CPG mapping, as discussed below in Section 3.2 through 3.6.

Lastly, with regard to Region 2's skepticism that an 80% reduction is achievable with a relatively small footprint, it should also be noted that the overall concentration reduction of a targeted remedy cannot be estimated by evaluating the mapping alone due to the dynamic interactions between target and non-target areas. As described in the 17-mile Draft RI Report (Anchor QEA et al. 2015), the major source of 2,3,7,8-TCDD to the water column is the LPR sediments and it is therefore expected that controlling this source will accelerate recovery in non-target areas, particularly those that are net depositional in nature. Capturing these effects is one of the reasons a contaminant fate and transport (CFT) model is employed in evaluating risk reductions in the FS, and the mapping should provide a reasonable representation of concentration patterns to that end.

## 3.2 Testing Target Delineation in the River Mile 10.9 Area

### *3.2.1 Region 2's Test*

Section 6.2 of the White Paper describes an analysis aimed at testing the ability of RI data to define areas above and below a RAL and to represent concentration levels pre- and post-remediation (assuming areas remediated go to zero concentration). The analysis used 1.2 miles of the river (RMs 10.5 to 11.7; 59.7 acres), which is significantly larger than the area around RM 10.9 with design scale data. A concentration map was generated using a portion of the RI data and was used to delineate a remedial footprint using a 500 ng/kg RAL. A second map representing the "true" concentration pattern was generated using all the RI data and RM 10.9 design data, upon which the remedial footprint from the first map was overlaid. Post-remedial SWACs and percent reduction in average concentration statistics resulting from the two maps indicated that the map generated from a portion of the RI dataset yielded an overstated benefit of remediation.

### *3.2.2 Region 2's Test Is Unreliable and Tests the Robustness of the Delineation of Target Areas, Rather than the Robustness of the Remedial Benefit Prediction Derived from the Mapping Approach*

Two aspects of Region 2's test invalidate its conclusions: 1) it considers an area that extends far beyond the region where design scale data exist (Figure 3-4); and 2) it does not test the map presented in the Draft 17-mile RI Report; rather it tests a cruder map generated using only a portion of the RI data.

The design scale data cover an area of 13 acres, which is only 22% of the 60 acres included in the test. Within this 13-acre area, the sample density increases from 0.9 to 7.7 cores per acre. Only here can there be a comparison to the "true" concentration pattern, and that comparison should have been done using the map in the Draft 17-mile RI Report that was developed using all the RI data.

Figure 3-5 shows the supposed "RI-dataset" used by Region 2 (left panel) and the full RI-dataset (excluding the RM 10.9 design data) on the right panel. Note the paucity of data that Region 2 relied on to develop a map to test. It is unclear why Region 2 tested a cruder map instead of one that uses all available RI data in the same manner as the Draft 17-mile RI Report map. The data excluded from the Region 2 map are an important part of the mapping that is critiqued in the White Paper and had been collected to address recognized data gaps. From the start, the exercise was not a well-constructed test of the CPG mapping.

Moreover, given that the FS is the context of the mapping, the CPG disagrees with the approach Region 2 used to assess forecasted and "actual" remedial benefit. By overlaying the remedial targets developed from the first map onto the second map with additional data, Region 2 tests the robustness of the precise delineation of target areas, rather than the robustness of the remedial benefit prediction derived from the mapping approach. As noted in several places throughout this response, the FS mapping seeks to reasonably represent concentration patterns to support remedial benefit evaluation with available data, and these representations are subject to change as new data and/or insights become available. As the mapping is updated, the delineation of target areas for a given RAL will also shift. The remedial benefit (i.e., pre- and post-remediation SWACs) should therefore be computed using updated remedial target areas. By applying targets based on an older map with less data, Region 2 is mainly testing the accuracy of the exact delineation made with its map, not whether the FS remedial benefit evaluation of a given RAL is likely to change or is biased. The uncertainty in the target area delineation will be resolved during the design phase with the collection of a much denser dataset (e.g., such as the one at RM 10.9).

The Region 2 analysis of RM 10.9 is neither conceptually nor methodologically sound. The correct test should compare projected forecasts with all RI data to updated forecasts with all available data (i.e., including the RM 10.9 design data). The analysis should consider only the 13-acre area where high density data were collected. The CPG performed this analysis and the results are detailed in the following section.

### *3.2.3 Proper Evaluation of the River Mile 10.9 CPG Map and Target Delineation Supports Its Use for Feasibility Study-level Alternatives Evaluation*

The CPG repeated the test, correcting the flaws in the Region 2 test:

- The study area was limited to the extent of the RM 10.9 design data.[8]
- The RI dataset includes all available RI data (with the exception of RM 10.9 design data).[9]
- The most recent mapping groups as presented in the Draft 17-mile RI Report were used.[10]

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[8] The study area was selected by generating a concave hull around the RM 10.9 design data. A distance threshold of 1,000 feet was used, a 40-foot buffer was added, and the final extent was clipped to the shoreline. A 40-foot buffer was selected because the design data were sampled at an approximate 40-foot grid structure. The area is 13.0 acres.

[9] Data in the study area were collected between 2008 and 2013.

[10] This version of the mapping was shared with the USEPA Region 2 on March 25, 2015, and is explained in detail in Appendix J of the Draft 17-mile RI Report (Anchor QEA et al. 2015).

The RI scale and design scale maps are shown in the left and right panels of Figure 3-6, respectively. Remedial footprints were generated using a 500 ng/kg RAL, for each of the two maps separately. Percent reduction in concentration and other parameters derived from the targeted remediation are presented in Table 3-1. The two maps yield the same percent reduction in SWAC of 97%. The design scale map shows a net 1-acre (7.3%) change in the area meeting the RAL, indicating the adequacy of the CPG's FS-level mapping to realistically represent a targeted remedy footprint.

The results of the only rigorous test that can be conducted at this stage show that the CPG method of mapping provides a reasonable basis for crafting targeted remedy alternatives for the FS.

## 3.3 Mapping Changes Between 2013 and 2015

### *3.3.1 Region 2's Position*

Section 4.2 of the Region 2 White Paper examines concentration differences between the 2013 and 2015 versions of the surface concentration mapping. It highlights three areas, depicted in Figure 7 of the White Paper, and describes the changes in concentration between the two versions of the mapping. From the differences, Region 2 concludes:

> *Illustrated sensitivity to small changes in the supporting data suggests that the Mapping Approach is unlikely to be reliable for forecasting values at unsampled locations or under future erosion and deposition. This sensitivity to new data or small changes in data handling decisions is symptomatic of models that are overly tailored to observed relationships in sample data and therefore do not generalize well, and suggest that there are likely significant inaccuracies in the estimated SWAC vs. RAL.*

### *3.3.2 Region 2 Misunderstands and Mischaracterizes the Mapping Changes*

In all scientific endeavors, methodology evolves as knowledge is gained. New data and information are used to refine understanding and improve methods. The development of the CPG's mapping approach is no different. Between the 2013 and 2015 mapping, modifications in methodology stemmed from a better understanding of the system and were a response to

Region 2 feedback. These changes in mapped concentrations are the result of model improvements and do not invalidate the approach.

Figure 3-7 shows the three areas (referred to as polygons) that Region 2 highlighted as evidence of sensitivity of the mapping to small changes in supporting data. It also explains the reasons for those cited changes, which the White Paper seems unaware of. In the 2013 mapping, Polygon A was set at the average concentration of all samples between RMs 2 and 7.8 collected in the portion of the river channel identified as being highly depositional (what is termed Group 4[11]). The 2015 map differs because the use of such a large-scale average was replaced by Thiessen polygons to better represent the local condition given the concentration variations within the interpolation groups. Similarly, the treatment of Polygon C changed from relying on a large-scale average for non-depositional areas of the channel (termed Group 2) to using Thiessen polygons.[12]

Polygon B is in a portion of the channel that experienced some deposition but may be subject to periodic erosion or may have reached geomorphic equilibrium. In the 2013 mapping, this mixed depositional portion was divided into two groups (termed Groups 3a and 3b). Based on comments made by the consultant for the State of New Jersey (LimnoTech 2013) and supported by Region 2, the CPG's 2015 mapping does not sub-divide the mixed depositional grouping. Combining Groups 3a and 3b[13] into one mixed depositional group (termed Group 3) increased data density and reduced the distance over which data was interpolated to assign a concentration to Polygon B.

The changes between the 2013 and 2015 mapping highlighted by Region 2 reflect refinements aimed at improving the mapping rather than invalidating the mapping approach as the Region believes. The goal of the mapping is to generate a reasonable representation of

[11] The 2015 mapping Groups are explained in detail in Appendix J of the 2015 Draft 17-mile RI Report (Anchor QEA et al. 2015).

[12] The CPG switched from using averages for Groups 2 (no deposition) and 4 (highly depositional) in the 2013 mapping to using Thiessen polygons in the 2015 mapping. In the 2015 mapping, the CPG decided to use the Thiessen polygon interpolation method everywhere, including in Groups 2 and 4, so that the same method of interpolation was used for all groups throughout the river.

[13] The 2013 mapping Groups are explained in detail in the Anchor QEA 2013 Contaminant Mapping Memorandum (Anchor QEA 2013).

the contaminant distribution for FS-level evaluations, and adjustments to that representation are expected as new data become available or as new insights are gained. The mere fact that the maps changed is not presumptive evidence that they are unreliable overall, and the White Paper's suggestion to this effect implies an unrealistic standard for the small-scale accuracy of the FS mapping.

## 3.4 Region 2's Use of SSP2 Data to Test Earlier Mapping

### *3.4.1 Region 2's Position*

Region 2 compared SSP2 data to the 2013 mapping that did not include the SSP2 data, as if the SSP2 data were collected to test the 2013 map. The SSP2 data included in this analysis were collected to further characterize the nature and extent of sediment chemistry and to fill data needs above RM 8 (i.e., locations selected to fulfil Data Quality Objective [DQO] No. 1).[14] Region 2 concluded that the differences between the SSP2 data concentrations mapped prior to the collection of the SSP2 data demonstrate flaws and biases in the mapping.

### *3.4.2 Region 2 Misapplies the SSP2 Data to Test the Mapping*

The SSP2 data were not collected to test the mapping. As stated in the Quality Assurance Project Plan (QAPP), "additional data will support the interpolation and mapping of measured surface and subsurface sediment concentrations to a continuous surface for initialization of the model grid. Locations were selected to reduce the uncertainty associated with the interpolation observed in the initial mapping results" (see Worksheet No. 10 of the SSP2 QAPP; AECOM 2013). Additionally, SSP2 data were collected in areas where existing data were sparse (DQO No. 1), in areas where the mapping may have been weak, and where new data could improve the mapping.

SSP2 sampling locations were selected through an iterative process between Region 2 and the CPG. In most cases, they were targeted where existing data were judged to be insufficient, based on insights gained from studying the rest of the river. That the resulting

[14] The SSP2 had two stated DQOs: 1) to provide additional characterization of the nature and extent of sediment chemistry and fill data needs above RM 8, as identified by USEPA; and 2) to provide data to support system understanding, sediment surface concentration mapping, and sediment transport and CFT model parameterization.

concentrations differ from the old mapping (see White Paper Figures 9 and 10) confirms what was generally expected. For example, SSP2 samples were sited to address concern with mapped high concentrations in sediment identified as coarse in side scan sonar. These high concentrations were from finer sediments found within a generally coarse area. Anticipating that they were finer pockets not characteristic of the coarse deposit, samples were collected in SSP2 to bound the extent of elevated concentrations. Therefore, finding lower concentrations is no surprise and consistent with the system understanding. The samples were not collected with the expectation of confirming the high concentration polygon.

The SSP2 dataset illustrates the value of additional data, such as those that would be collected during a remedial design program, in refining the concentration maps and target area delineations. This is to be expected; sediment contaminant concentration maps will always be improved with additional data regardless of the mapping approach used. It is not reasonable for Region 2 to suggest that this inescapable fact somehow invalidates the CPG mapping approach.

## 3.5 Region 2's Statistical Simulation to Evaluate Targeted Remedy Delineation

### *3.5.1 Region 2 Position*

Region 2 crafted a computer simulation study to test the concentration reductions indicated by a targeted remedy developed using the CPG COPC map. The simulation was meant to generate datasets statistically similar to actual data from the left shoal, right shoal, and channel of the LPR in the vicinity of RMs 9 to 11. Its results suggest that using the CPG approach to delineate a remedial footprint understates the post-remedial SWAC and the footprint size associated with a 500 ng/kg 2,3,7,8-TCDD RAL. The White Paper goes on to state that the CPG assessment of a targeted remedy "is likely to be inaccurate and cannot be relied upon to support decision making for the LPRSA".

### *3.5.2 Region 2's Statistical Simulation Is Not a Valid Test of CPG Mapping*

Region 2's simulation and its interpretation are flawed for two main reasons: 1) the simulation misrepresents the CPG approach to Targeted Remedy delineation because it relies on arbitrarily defined target/non-target areas (termed "decision units") that take no account of the underlying concentration patterns; and 2) biased simulation results are guaranteed by the simulation input and construction.

#### 3.5.2.1 Region 2 Misrepresents the CPG Approach to Targeted Remedy Delineation

The central question in defining a targeted remedy is whether it is reasonable to identify and target areas in which concentrations are consistently above a RAL. In other words, are concentration patterns sufficiently organized (i.e., spatially correlated) such that regions of generally high concentrations can be separated from regions of generally low concentrations? As discussed in the earlier sections, such correlation comes from consistency in erosion and deposition behavior and sediment type, and can be discerned in the RI data. Multiple examples of this are presented in the Draft 17-mile RI Report, in a presentation to Region 2 on March 11, 2015 (Appendix A), and in this document. Section 2 demonstrated, using the high density data within the RM 10.9 shoal, where coherent patterns in contaminant concentration can be explained by considering the evolution of the shoal and the variation in characteristics such as depositional history, sediment type, and hydrodynamic conditions (see Section 2.2.1 and Figure 2-4). The CPG believes that similar coherent areas of high concentrations exist throughout the LPR at scales such that they can be preliminarily targeted using the RI data and fully identified following a pre-design sampling program.

Consequently, the CPG approach to targeted remedy delineation in the FS is to define target and non-target areas using decision units at or below the scale over which concentrations are correlated, thereby separating regions of low and high concentration. Thiessen polygons constrained by geomorphic features are used to define decision units. They are an approximation of the actual concentration patterns because they do not reproduce concentration variability within the polygons and concentrations change sharply between polygons. However, on a larger scale they reproduce the concentration distribution observed in the available data and thereby offer a reasonable representation for the FS of the remedial benefit of tailoring decision units to address areas of elevated concentration, which would be more precisely characterized in a future high-density remedial design sampling.

Region 2's statistical simulation ignores the basic characteristic of a targeted remedy by defining target and non-target areas using decision units much greater than the area over which concentrations are correlated, thus including regions of low and high concentrations. The decision units considered in the White Paper's simulation study are shown as the black boxes in Figure 3-8 (Figure 17 from the White Paper). They clearly extend beyond the distance over which concentrations are correlated (note in Figure 3-8 the spatial structure of high and low concentration within and across Region 2's defined decision units). When the decision unit is larger than the scale of the correlation, the assessment of a targeted remedy loses meaning as nothing is really being targeted. An appropriate decision unit would need to be defined on the scale of spatial correlation such that these areas are identified separately. Defining areas for the purpose of crafting remedial alternatives without adequately considering the underlying concentration pattern, as done in the simulation, is not appropriate.

The shortcoming of the White Paper's approach to defining target areas is illustrated by considering the correspondence between the simulation study example concentration field and the RM 10.9 deposit where high density was collected during remedial design (Figure 3-9). As discussed in Section 2.2.1, prior to remediation there existed a distinct region of elevated concentrations, which transitioned to lower concentrations after the bend in the river (see the data that are contained approximately within the 0 and -7 bathymetric contours in Figure 3-9 [top panel]). This organized pattern, which results from the physical characteristics and history of the deposit, allowed for the delineation of a targeted removal within this area. Similar coherent patterns are known to exist elsewhere and are expected throughout the LPR, such that regions of high concentrations can be targeted with appropriately sized decision units. The simulation study does not test such targeting because it uses decision units that do not resolve concentration correlations on a smaller scale, such that areas of high and low concentrations are not adequately distinguished (Figure 3-9, bottom panel). Region 2's simulation study is not a valid representation of an FS-level evaluation, and is not a relevant assessment of CPG's approach to mapping and target delineation for the FS.

#### *3.5.2.2 The Simulation Results Are Guaranteed by the Simulation Input and Construction*

The simulation results and the conclusions Region 2 draws from them are completely predetermined by the mathematical structure, which has little reality associated with it. They simply reflect the chosen concentration distribution and setting the size of the decision unit to be larger than the scale of correlation.

The major conclusions drawn from the simulation study derive from the left panels of Figure 3-10 (Figure 19 from the White Paper), which summarizes the results of conducting the following remedial benefit calculation for each of 1,000 different realizations of the randomized concentration field:

1. Randomly select a concentration value from within each decision unit and take this value to represent the Predicted Average concentration of that unit (this is considered an approximation of the CPG's Thiessen polygon approach).
2. For decision units with a Predicted Average at or above the 500 ng/kg RAL, simulate remediation by assigning a post-remedial concentration of 0 ng/kg. For all other decision units, use the Predicted Average from Step 1 as the predicted post-remedial concentration.
3. Calculate a Predicted Post Remedial SWAC across all decision units using the post-remedial concentrations from Step 2; this quantity is shown on the horizontal axis of the upper left panel of Figure 3-10.
4. Compare this value to an Actual Post Remedial SWAC across all decision units, calculated by repeating Step 3 using instead the actual (or "true") decision unit average concentrations for non-remediated cells; this quantity is shown on the vertical axis of the upper left panel of Figure 3-10.

The choice of the input distribution and the large size of the decision units relative to the correlation length cause the Predicted Average concentration for each decision unit (see Step 1 above) to most often be less than the actual ("true") average, due to the nature of the log-normal input distribution from which the random concentration field was generated (Figure 3-11, showing an example of Region 2's input distributions). The likelihood of picking values at or above the "true" average in a majority of the decision units is vanishingly small, given the approximate one-in-five chance of doing so in each unit, and consequently the predicted average concentration across all decision units will almost always be lower than the "true" average. In the evaluation of remedial benefit, consistently under-predicting the average of decision units causes some units that should be remediated to not be, thus leaving contaminant mass behind. This behavior gives rise to the result in the left panels of Figure 3-10 that the Predicted Post Remedial SWAC across all decision units is less than the Actual Post Remedial SWAC in 999 of 1,000 simulations. This behavior also causes the targeting of less total area for remediation relative to the area that would have been targeted using the true average of decision units, as shown in the footprint comparisons in the right panels of Figure 3-10.

Given that the simulation uses decision units that are arbitrarily large relative to the scale of spatial correlation and that the results of the simulation are pre-determined by construction, the CPG sees no utility in the simulation or the conclusions drawn from it.

## 3.6 Region 2's Recommendation to Use Large-scale Averages

### *3.6.1 Region 2's Position*

Section 7 of the Region 2 White Paper suggests "restricting usage of mapped values to estimation of site-wide average concentration, imputation of surface averages as model initial conditions within relatively large areas, and for developing weighted averages within relatively large subareas of the LPRSA that might be used to forecast remedial options." It also requests that the CPG "[c]onsider assuring that areas for which averages are to be calculated are spatially contiguous and include multiple replicate samples (i.e., several Thiessen polygons)."

### *3.6.2 Region 2's Position Would Degrade the Mapping of Concentrations*

Large-scale averaging such as averaging over geomorphic features (as Region 2 has previously done; LBG et al. 2014) misrepresents the local patterns in concentration that are clearly visible on maps, and would result in a targeted remediation that leaves high concentration areas untouched and targets areas of low concentration. Moreover, it fails to recognize the evolution of geomorphologic features of the LPR and the nature of contaminant release and transport. In essence, it degrades the mapping of the river, increasing deviations between the map and the underlying data. Examples of these deviations for several Region 2 geomorphic regions are shown in Figure 3-12, which presents measured surface concentrations on the left and the deviation of those concentrations from a mapped average[15] on the right. The abundance of red markers throughout the lower 13 miles indicates the propensity of Region 2's methodology to grossly under- or over-estimate actual concentrations. Selected examples from Figures 3-12a through 3-12i are discussed in more detail below.

Eight out of the ten samples presented in Figure 3-12a have surface 2,3,7,8-TCDD concentrations less than 250 ng/kg. However, the average concentration of 1,730 ng/kg within this geomorphic region is inflated by a single high concentration sample at the extreme downstream edge of the geomorphic unit—using this average value for the entire unit results in all samples below the RAL being classified as above the RAL and misrepresents the concentrations by more than 1,000 ng/kg. The high concentration is from a silt pocket at that location—the rest of the region comprises coarser sediments (see Section 4.1 of the Draft 17-mile RI Report [Anchor QEA et al. 2015], which explicitly mentions this sample). Assigning an average concentration to the entire geomorphic region that is so heavily impacted by a single non-representative sample is fallacious.

A similar set of maps are presented for the RM 10.9 area in Figure 3-12b. As discussed previously (Section 2.2; also Section 4.1 of the Draft 17-mile RI Report [Anchor QEA et al. 2015]), the surface contamination trends in the RM 10.9 point bar follow logically from the evolution of the point bar. Using a mapped average ignores the physical processes that form a point bar, resulting in significantly overestimating the concentrations at the downstream parts of the point bar, and significantly underestimating the concentrations in the upstream parts of the point bar.

The stretch of the LPR between RMs 8 and 9 is presented in Figure 3-12d. The eastern and western shoals are parts of two geomorphic units. The eastern unit exhibits a clear spatial pattern with the highest concentrations in the northern portion next to the bridge abutment.

[15] Averages were calculated using the CPG mapping's 2005-2013 surface sediment dataset for the geomorphic regions used by Region 2 in the Focused Feasibility Study (LBG et al. 2014).

The average loses this spatial pattern and misrepresents concentrations everywhere. The average concentration of the western unit is driven by the two samples in excess of 10,000 ng/kg, both of which reflect unique conditions. The sample at approximately RM 8.6 is likely associated with the bridge abutment mentioned above. The sample at RM 8.8 has a fine sediment content of 61%, even though the unit is composed of gravel and sand. This fine-sediment pocket is not representative of the largely coarse sediments present in this unit (see Section 4.1 of the Draft 17-mile RI Report [Anchor QEA et al. 2015] for a discussion of the fine sediment pockets observed in regions classified as coarse by side scan sonar). The result of not identifying the physical reasons responsible for these concentration trends results in the significant overestimation or underestimation of concentrations.

At RM 3.63, an elevated concentration in the middle of the channel results in an artificially high average concentration for the entire unit (Figure 3-12h). This elevated concentration, however, is because the sample was collected at a location that scoured during Hurricane Irene (see Sections 3.7 and 4.1 of the Draft 17-mile RI Report [Anchor QEA et al. 2015], which discusses this location in more detail). The surrounding sample locations did not scour during Irene, and this elevated point is not representative of the rest of the unit. The result of using the average is the misclassification of low contamination locations as highly contaminated.

The contamination patterns observed in the LPR are based on fundamental physical, fluvial, and sedimentological processes. Using an average concentration to estimate contamination in the LPR is incorrect in that it misrepresents the contaminant distribution in the river. Such a calculation masks real patterns in sediment contaminant concentrations. Averaging over geomorphic areas is a deficient representation of the river and an inaccurate method for crafting remedial alternatives.

# 4 CONCLUSIONS

The CPG mapping is based on an expansive understanding of the river gained through the myriad studies conducted during the $125 million RI. It uses good science and a wealth of site-specific data to provide a reasonable representation of COPC concentrations that replicates coherent patterns and uses data stratifications rooted in system understanding. It is consistent with the mapping USEPA typically uses at CERCLA sites to meet the needs of an RI and FS. It is validated by the design level data at RM 10.9, which show its good performance in identifying areas meeting a specified RAL and assessing the reductions in average concentration achieved by remediation.

Region 2's White Paper sets an unachievable and unnecessary standard of accuracy that is unprecedented and inconsistent with RI/FS-level investigations. The White Paper seems to have centered its evaluation of the mapping on its ability to exactly delineate remedial target areas, which is an inappropriate standard for an FS-level analysis. Rather, the goal of the COPC mapping in the FS is to achieve a reasonable representation of the concentration distribution from which an approximate remedial footprint can be delineated and used to evaluate relative remedial benefit. The refined boundaries of target areas will be developed when new data are collected, particularly during the design phase when high density data would become available following the remedial design investigation.

The White Paper's proposed alternative approach of large-scale averages is demonstrably less accurate and would lead to poorly developed remedial alternatives and a technically deficient FS. The 17-mile LPRSA FS evaluation should be based on a reasonable representation of the coherent patterns observed in the available data and should not be dictated by limitations of the present RI dataset to resolve those patterns to a level of accuracy inconsistent with FS-level evaluations. The CPG's COPC mapping meets the current standard of practice with regard to both technique and data density, as demonstrated by analysis of the RM 10.9 RI and characterization datasets. Region 2 has imposed a level of accuracy on the 17-mile RI/FS COPC Mapping and intolerance of uncertainty that is inconsistent with its own similar activities at other sites such as the Hudson River.

# 5 REFERENCES

AECOM, 2013. *Quality Assurance Project Plan. Lower Passaic River Study Area, Low Resolution Coring Second Supplemental Sampling Program*. Revision 1. September 2013.

Anchor QEA (Anchor QEA, LLC), 2013. Memorandum to Robert Law, de maximis, inc. Regarding: Lower Passaic River Surface Sediment Concentration Mapping. May 17, 2013.

Anchor QEA, AECOM, de maximis, inc., Integral Consulting, mab environmental, LLC, Moffatt & Nichol, and Windward Environmental LLC, 2015. *Remedial Investigation Report.* Remediation Investigation/Feasibility Study. Lower Passaic River Study Area. Prepared for Lower Passaic River Cooperating Parties Group. Draft, February 2015

Dalrymple, R.W. and K. Choi, 2007. Morphologic and Facies Trends through the Fluvial‐marine Transition in Tide-dominated Depositional Systems: A Schematic Framework for Environmental and Sequence-stratigraphic Interpretation. *Earth‐Science Reviews* 81:135-174.

Dalrymple, R.W. and R.N. Rhodes, 1995. Geomorphology and Sedimentology of Estuaries. *Developments in Sedimentology, Estuarine Dunes and Bars* 13: 359-415.

Fryirs, K.A. and G.J. Brierley, 2013. *Geomorphic Analysis of River Systems: An Approach to Reading the Landscape.*

Garvey, E. and J. Atmadja, 2012. Memorandum to Gary Klawinski, USEPA. Regarding: Comparison of ROD and SSAP-based Estimates of the Reduction in Surface Sediment. May 30, 2012. Appendix A in USEPA, 2012. *First Five-year Review Report for Hudson River PCBs Superfund Site.*

LBG (Louis Berger Group), Battelle, and HDR|HydroQual, 2014. *Remedial Investigation Report for the Focused Feasibility Study of the Lower Eight Miles of the Lower Passaic River.* Prepared for U.S. Environmental Protection Agency, Region 2, and the U.S. Army Corps of Engineers, Kansas City District.

LimnoTech, 2013. Memorandum to Janine McGregor, New Jersey Department of Environmental Protection. Regarding: Observations of Anchor QEA May 17, 2013 Lower Passaic River Surface Sediment Concentration Mapping. September 24, 2013.

QEA, LLC (Quantitative Environmental Analysis, LLC), 2007. *Hudson River PCBs Site. Phase 2 Dredge Area Delineation Report.* Prepared for the General Electric Company, Albany, New York. December 2007.

RETEC, 2002. *Final Feasibility Study.* Lower Fox River and Green Bay, Wisconsin. Remedial Investigation and Feasibility Study. Prepared for Wisconsin Department of Natural Resources. December 2002.

Sea Engineering and HQI (HDR|HydroQual), 2011. *Lower Passaic River system understanding of sediment transport.* Sea Engineering, Inc., Santa Cruz, California; HDR/HydroQual, Inc., Mahwah, New Jersey.

Tetra Tech EC, Inc., Anchor QEA, J.F. Brennan Co, Inc., and Stuyvesant Projects Realization, Inc., 2012. *Lower Fox River Remedial Design; 100 Percent Design Report for 2010 and Beyond Remedial Actions.* Prepared for Lower Fox River Remediation LLC. October 2012.

USEPA (U.S. Environmental Protection Agency), 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, EPA/540/G-89/004. October 1988.

USEPA, 2000. *Phase 3 Report: Feasibility Study.* Hudson River PCBs Reassessment RI/FS. USEPA, Region 2 and USACE, Kansas City District. December 2000.

Weston, R.F., 1999. Peer Review of the Remedial Investigation and Data Management Reports for the Lower Fox River Natural Resources Damage Assessment. Prepared by Roy F. Weston, Inc.

# TABLES

## Table 1-1
## Sampling Densities and Interpolation Methods at Several Contaminated Sediment Sites

| | | | | RI/FS | | | | Remedial Design | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Data (for primary COPC) | | | | Pre-remedial Design Data | | | |
| | | Size | | Number of Sampling Locations | Sampling Density (locations per…) | | | Number of Sampling Locations | Sampling Density (locations per…) | | |
| Site | COPC | Miles | Acres | | Acre | Mile | Aerial Interpolation Method | | Acre | Mile | Aerial Interpolation Method |
| Lower Passaic River | 2,3,7,8-TCDD, and others | 17 | 1,016 | 480 | 0.47 | 28 | River divided into groups and thiessen polygons were used to interpolate within groups | NA | | | |
| Portland Harbor | PCBs | 10 | 2,172 | 1,595 | 0.73 | 160 | Natural neighbors | NA | | | |
| | Dioxans/furans | | | 1,488 | 0.69 | 149 | | | | | |
| | PAHs | | | 2,040 | 0.94 | 204 | | | | | |
| | DDx | | | 356 | 0.16 | 36 | | | | | |
| Buffalo River* | PAH, PCB, Pb, and Hg | 8 | 289 | 391 | 1.35 | 51 | IDW | chemical 560 | 1.9 | 74 | Manual adjustments to FS delineation |
| | | | | | | | | probing 800 | 3 | 105 | |
| Upper Hudson River | PCBs | 40 | 4,456 | 2,303 | 0.52 | 58 | For RS1 and RS2, the river was divided into cohesive and non-cohesive, thiessen polygons within these areas. Hotspots targeted in RS3. | 11,550 | ~8 – 10 cores in target areas | ~290 | A combination of IDW, Kriging, and manual delineation |
| Lower Fox River** | PCBs | 39 | 3,100 | 900 | 0.29 | 23 | IDW | 3,660 | 1.6 | 105 | Indicator Kriging with river straightening |

Notes:

*For Buffalo River remedial design, chemical and probing data counts are shown separately. Probing was done to determine depth to till.

**For ease of comparison, only the Lower Fox River data used in the mapping to establish target areas in the river (not in Green Bay) are summarized (i.e., OU1 to OU4). Acreage is the estimated acreage of river bottom that had sediment deposits and consequently would have been amenable to sediment sampling. The remedial design data summary does not include OU1 and therefore is summarized for the lower 35 miles of river, which includes 2,326 acres of sediment.

2,3,7,8,-TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin
COPC = chemical of potential concern
FS = Feasibility Study
Hg = Mercury
IDW = Inverse Distance Weighted
NA = not applicable
PAH = polycyclic aromatic hydrocarbon
Pb = Lead
PCB = polychlorinated biphenyl
RI = Remedial Investigation
RS = river section

**Table 3-1**
**Surface-weighted Area Concentration**
**Estimates for RM 10.9 Design Area**

| | Exclude Design Data | Include All Data |
|---|---|---|
| Cores per acre | 0.9 | 7.7 |
| Pre-remedial SWAC (ng/kg) | 3,361 | 3,179 |
| Post-remedial SWAC (ng/kg) | 85 | 95 |
| Percentage SWAC reduction | 97% | 97% |
| Target area (acres) | 6.1 | 5.1 |
| Non-target area (acres) | 6.9 | 7.9 |
| Net percent area change | — | 7.3% |
| SWAC outside footprint (ng/kg) | 159 | 157 |
| SWAC within footprint (ng/kg) | 7,022 | 7,835 |

Notes:

Remedy footprints are generated based on individual interpolations.

Only includes the extent (13 acres) of the RM 10.9 design data as shown on Figure 3-2.

ng/kg = nanogram per kilogram

RM = river mile

SWAC = Surface-weighted Area Concentration

# FIGURES

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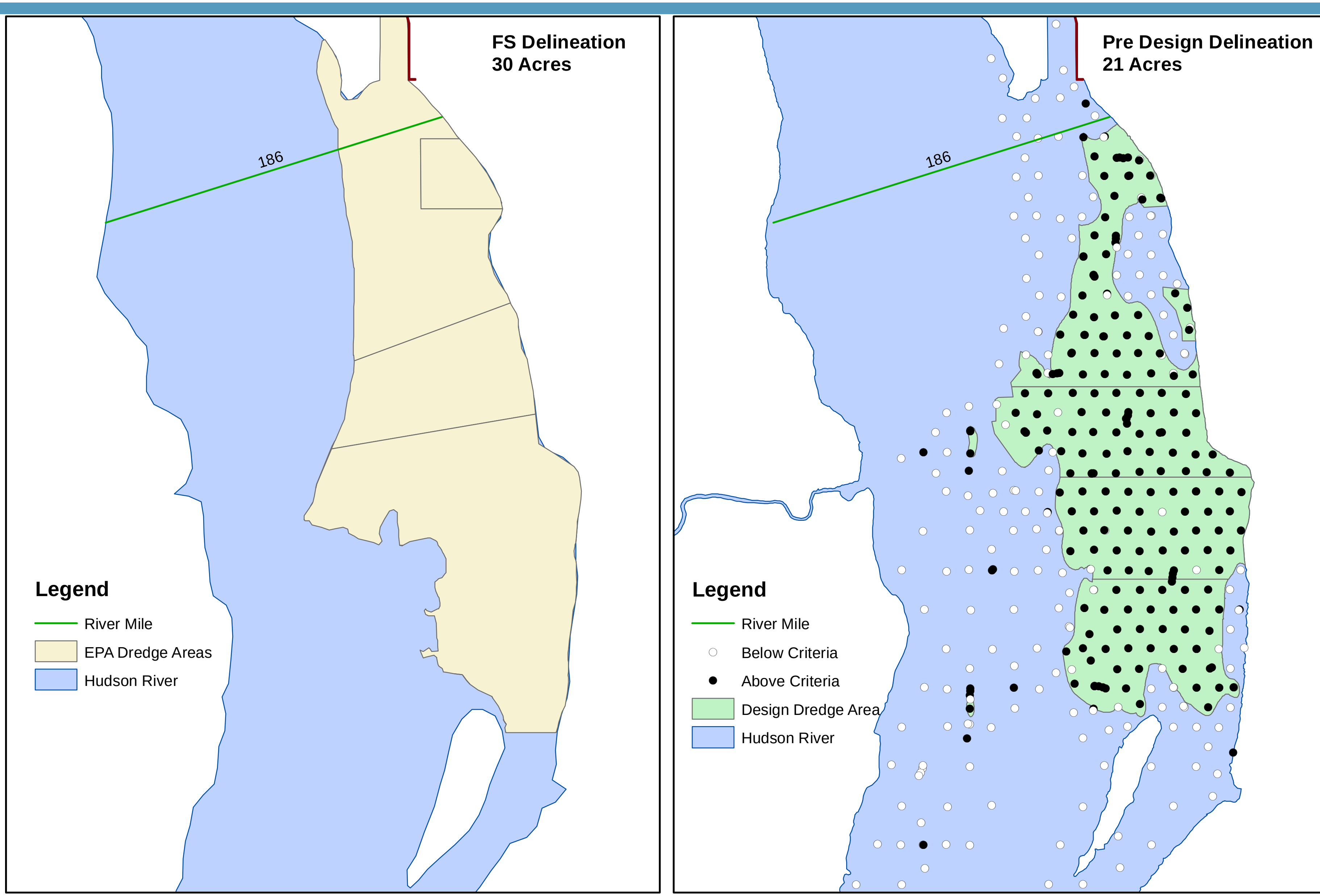


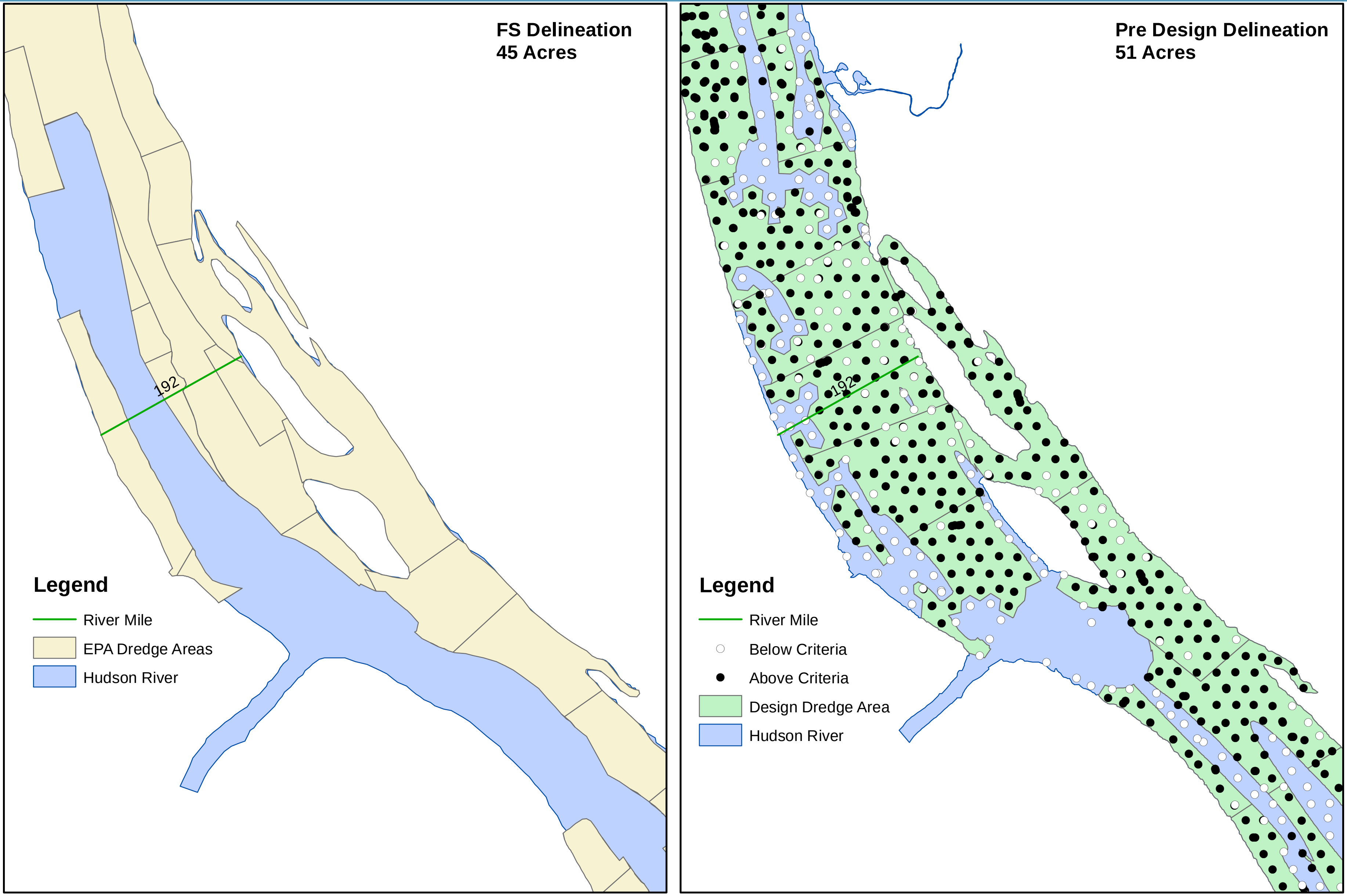

410 205 0 410 Feet

**Figure 1-1**

Comparison of Footprint Used in Upper Hudson River FS for Alternatives Evaluation to Final Footprint Delineated Using Pre-design Datasets Around RM 186

Contaminant Mapping Response

Lower Passaic River Study Area Remedial Investigation/Feasibility Study




500 250 0 500 Feet

**Figure 1-2**
Comparison of Footprint Used in Upper Hudson River FS for Alternatives Evaluation to Final Footprint Delineated Using Pre-design Datasets Around RM 192
Contaminant Mapping Response
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

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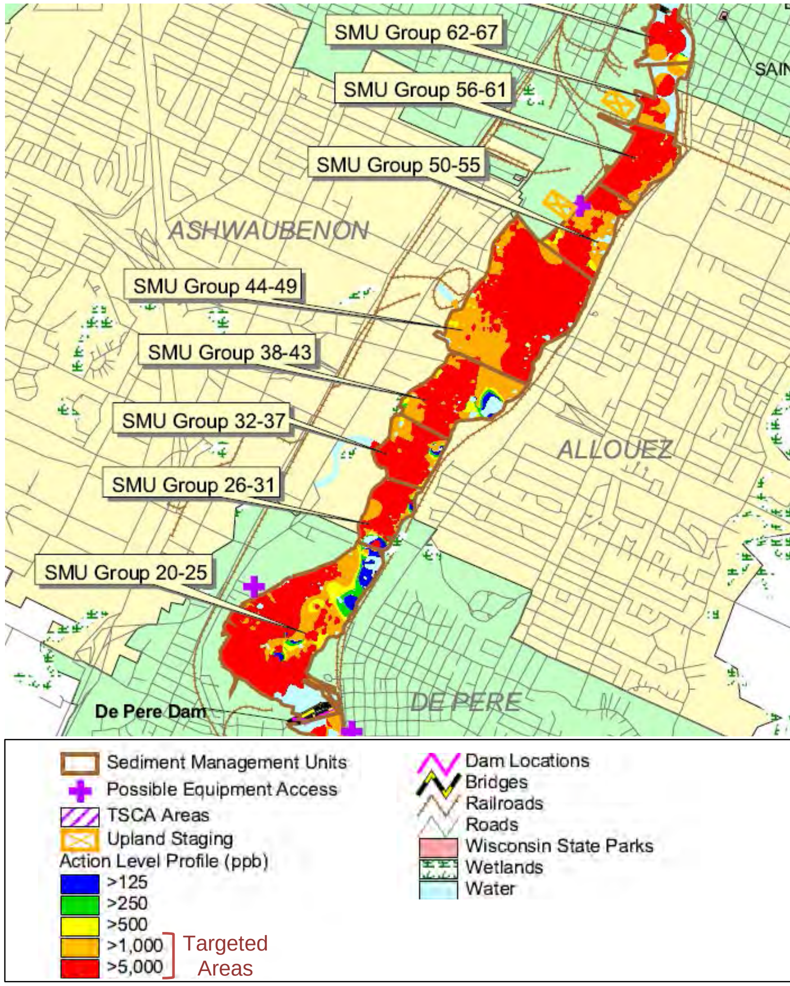
Delineation Using FS Mapping Technique
(RETEC 2002)




In the FS, all sediments above 1,000 ppb were targeted for remediation (red and orange in the above figure).

Delineation Using
Pre-design Dataset (Tetra Tech et al. 2012)

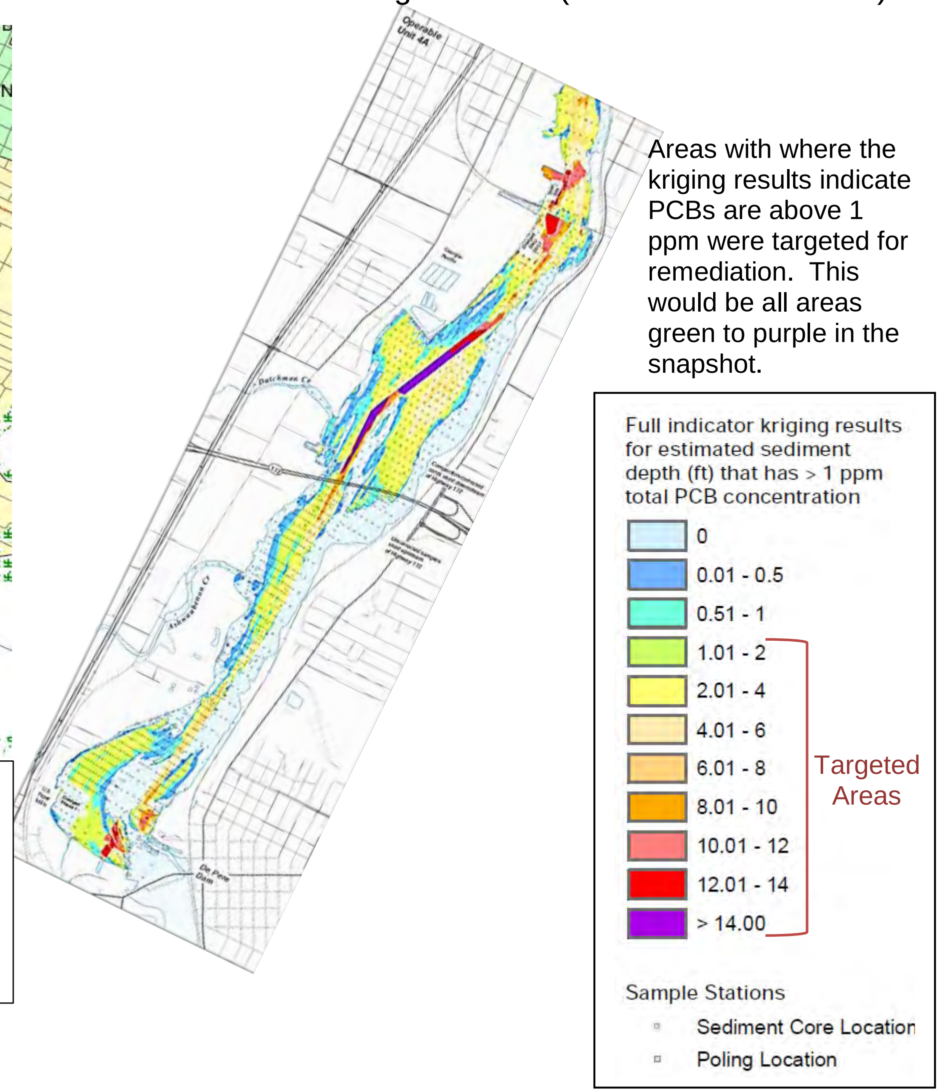



**Figure 1-3**
Comparison of Footprint Used in Lower Fox River FS for Alternatives Evaluation to Final Footprint Delineated Using Pre-design Datasets within OU4
Contaminant Mapping Response
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

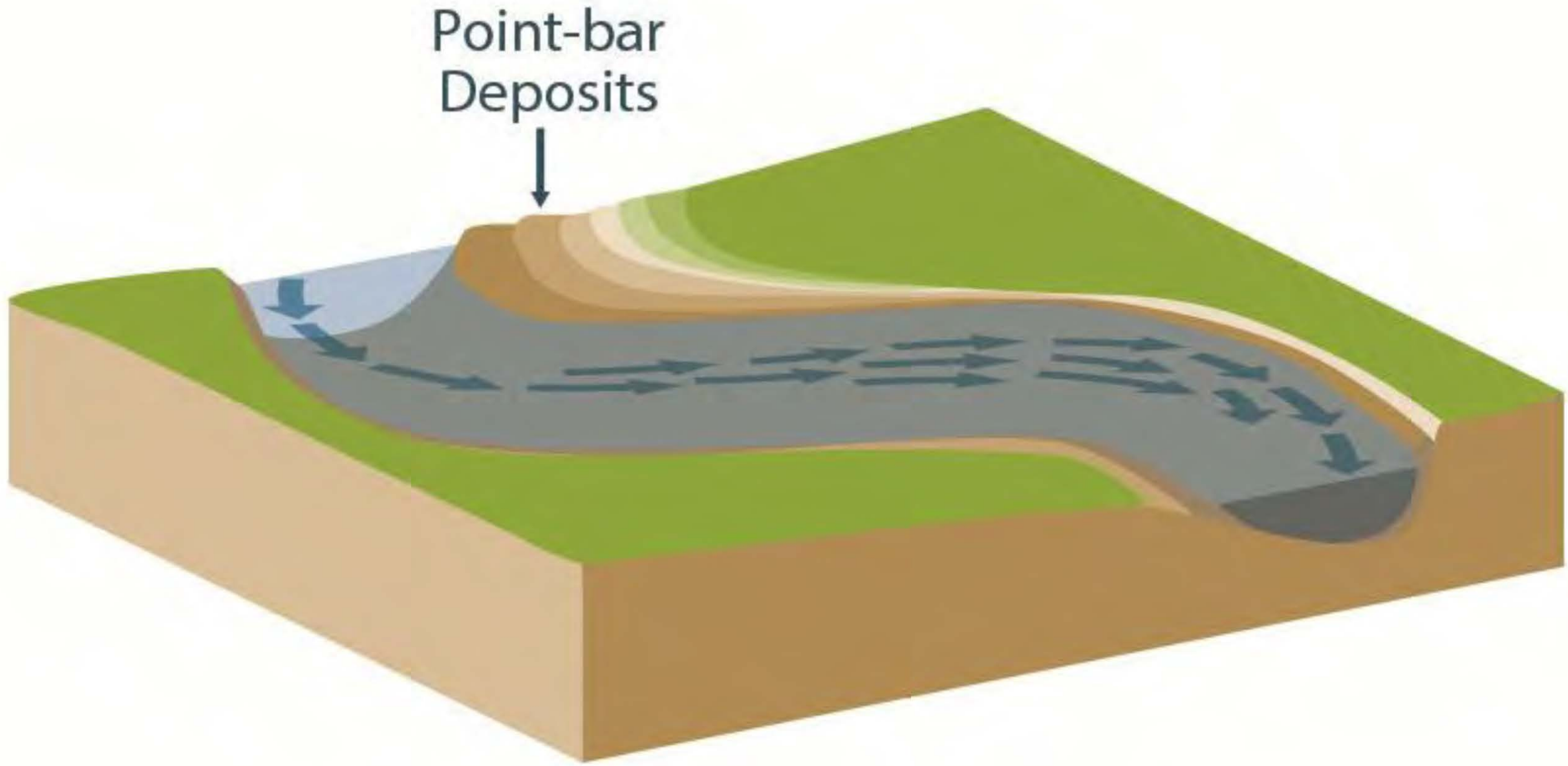



**Figure 2-1**
Conceptual Diagram of Point Bar Development Over Time
Contaminant Mapping Response
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

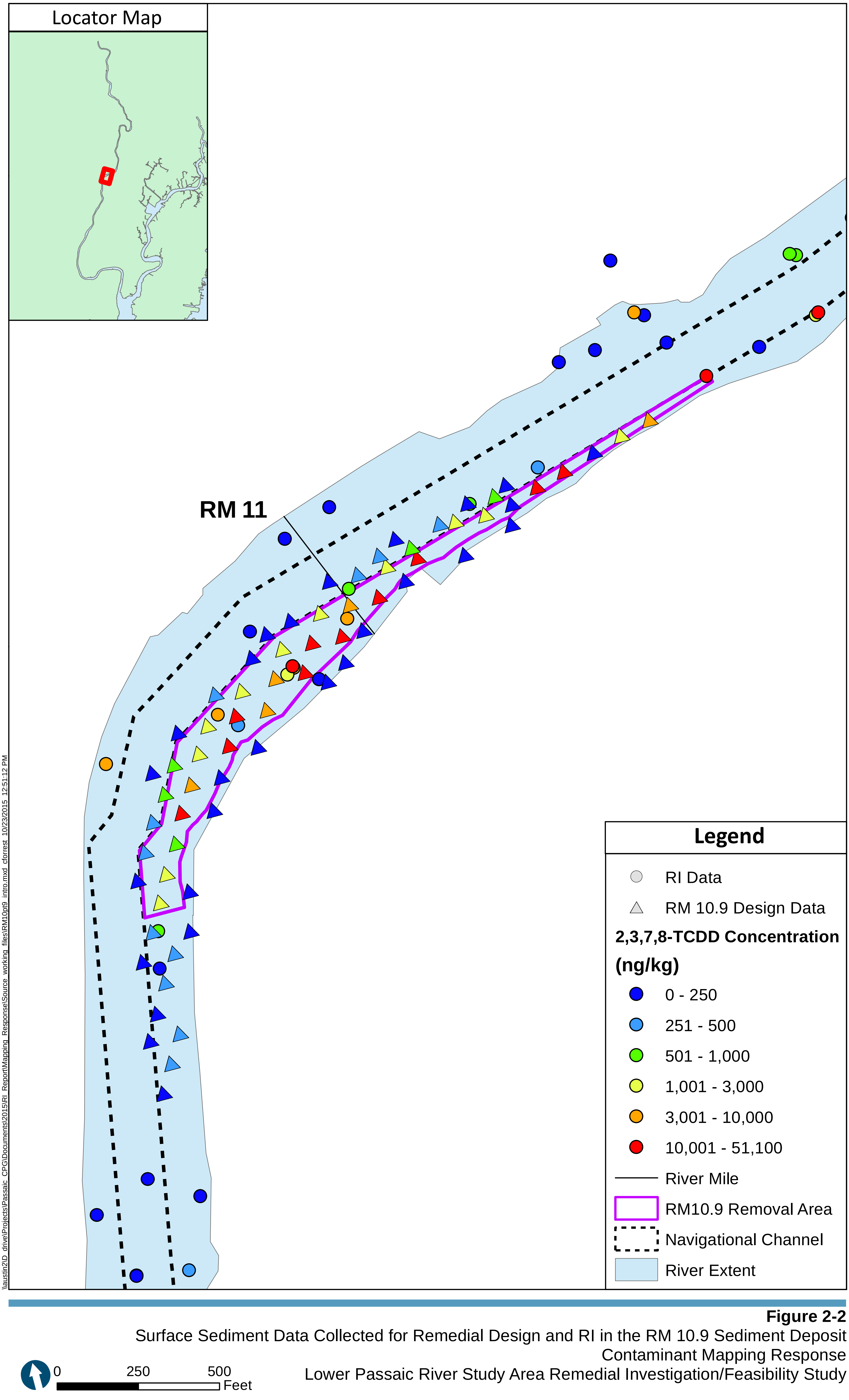
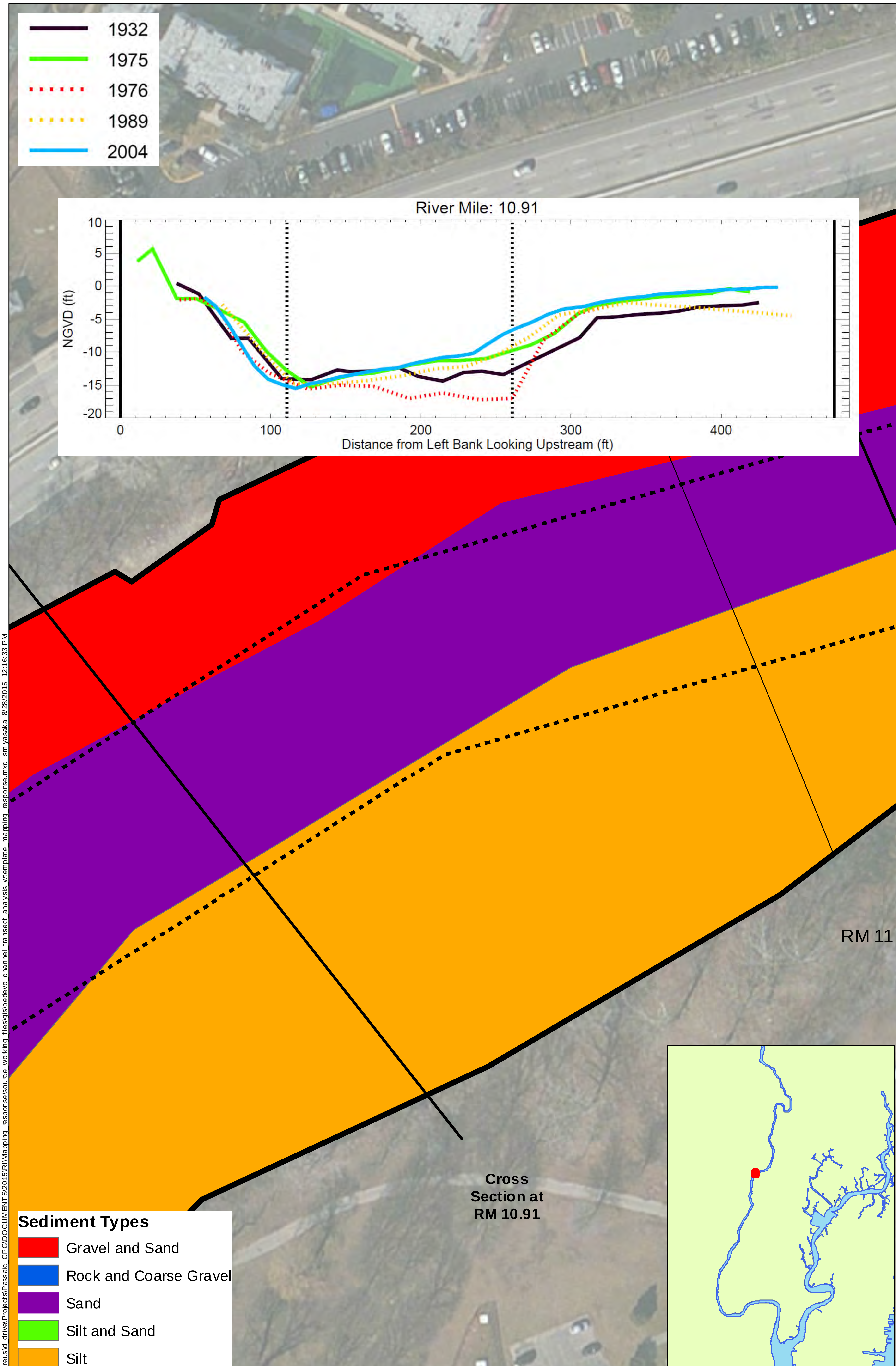



**Figure 2-2**
Surface Sediment Data Collected for Remedial Design and RI in the RM 10.9 Sediment Deposit
Contaminant Mapping Response
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

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Abutment
Navigational Channel
Shoreline

0 87.5 175 Feet

**Figure 2-3**

Historical Cross Sections of Bathymetry Near RM 10.9

Contaminant Mapping Response

Lower Passaic River Study Area Remedial Investigation/Feasibility Study

*Navigation channel in this stretch of the LPR was last dredged in 1976*

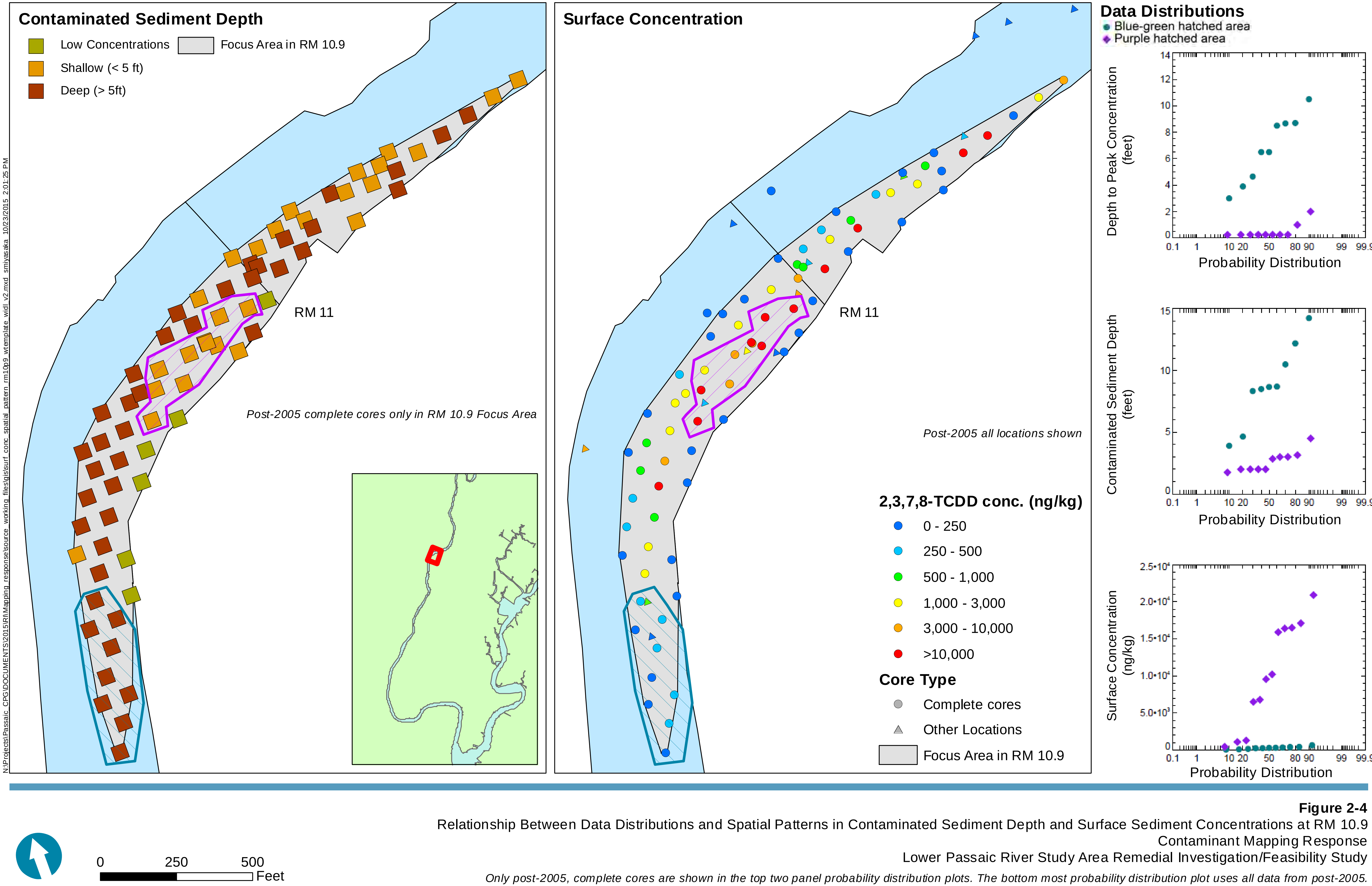


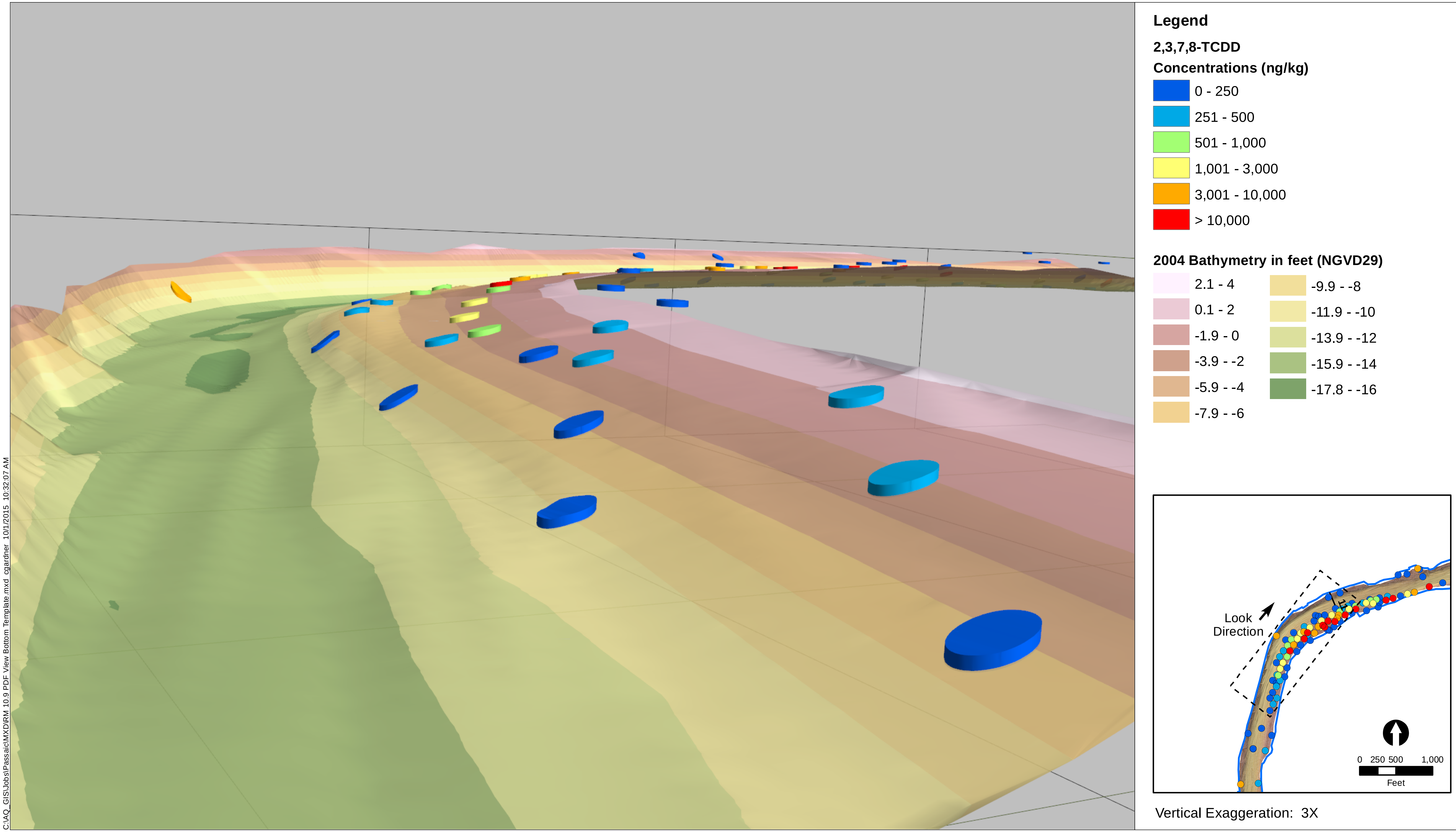

**Figure 2-4**

Relationship Between Data Distributions and Spatial Patterns in Contaminated Sediment Depth and Surface Sediment Concentrations at RM 10.9

Contaminant Mapping Response

Lower Passaic River Study Area Remedial Investigation/Feasibility Study

*Only post-2005, complete cores are shown in the top two panel probability distribution plots. The bottom most probability distribution plot uses all data from post-2005.*

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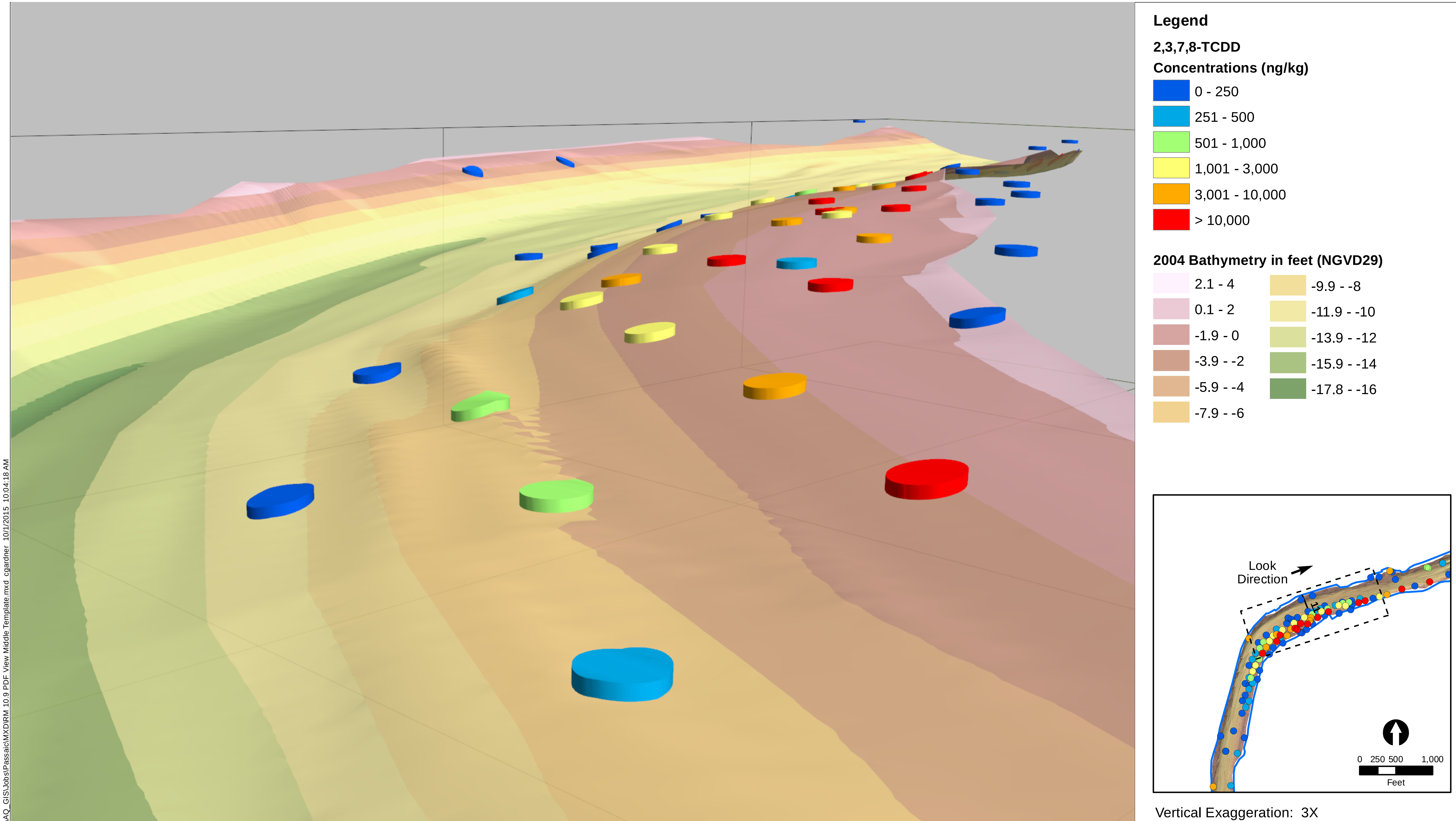
**Note:**
· Mudline elevations were not available for the samples appearing outside of the extent of the bathymetry. The base elevations for these samples have been arbitrarily established at +2 ft NGVD 29 to facilitate displaying them with the other samples in this figure.

**3D PDF Map Navigation Instructions:**
· Depress left mouse button + move mouse to rotate in all directions;
· Depress Ctrl button + left mouse button to pan;
· Rotate mouse wheel in/out to zoom in/out.

**Figure 2-5a**

2,3,7,8-TCDD Surface Sediment Concentrations over Bathymetry
Near RM 10.9 - View Bottom
Contaminant Mapping Response
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

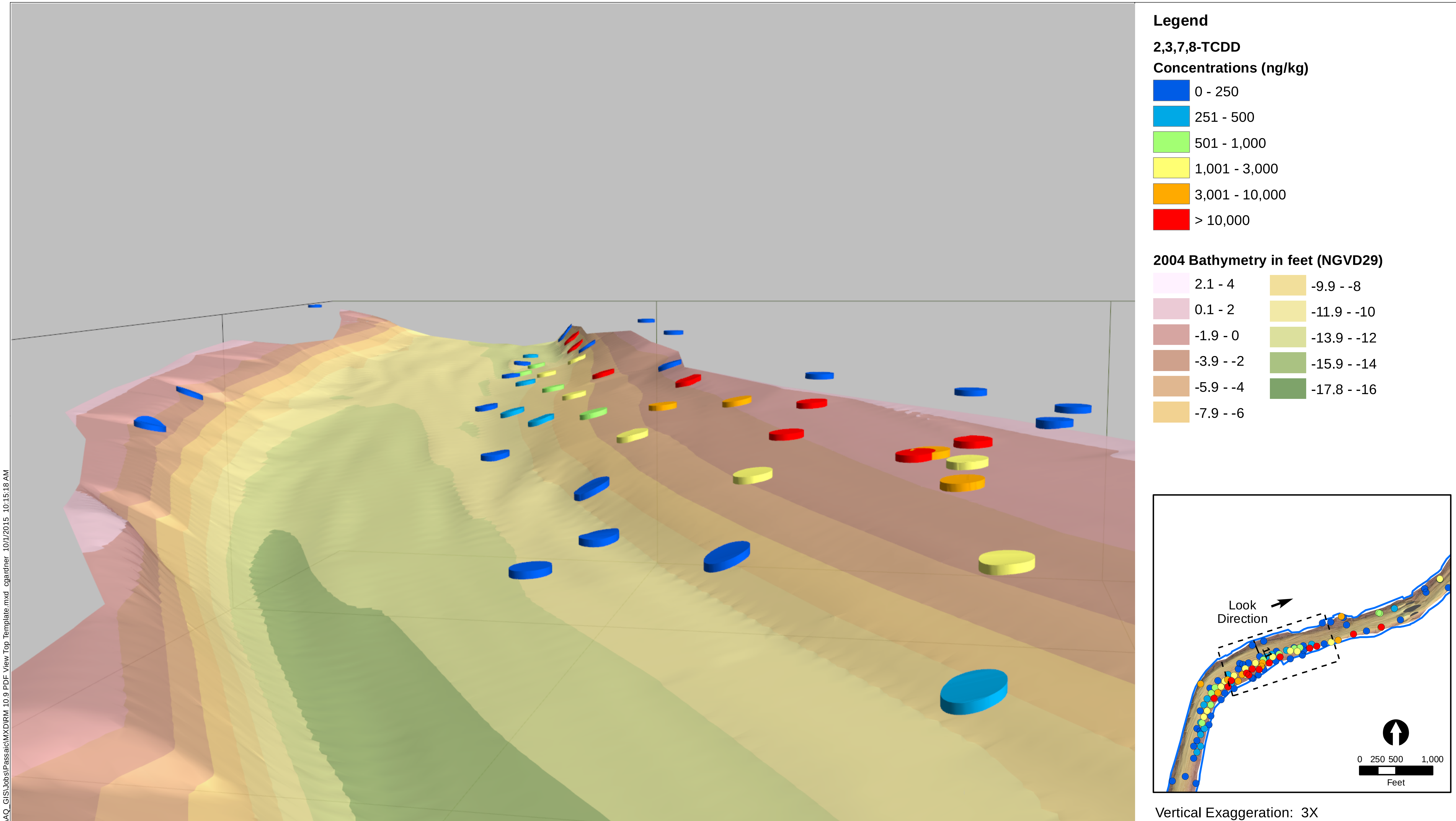



**Note:**
- Mudline elevations were not available for the samples appearing outside of the extent of the bathymetry. The base elevations for these samples have been arbitrarily established at +2 ft NGVD 29 to facilitate displaying them with the other samples in this figure.

**3D PDF Map Navigation Instructions:**
- Depress left mouse button + move mouse to rotate in all directions;
- Depress Ctrl button + left mouse button to pan;
- Rotate mouse wheel in/out to zoom in/out.

**Figure 2-5b**

2,3,7,8-TCDD Surface Sediment Concentrations over Bathymetry
Near RM 10.9 - View Middle
Contaminant Mapping Response
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

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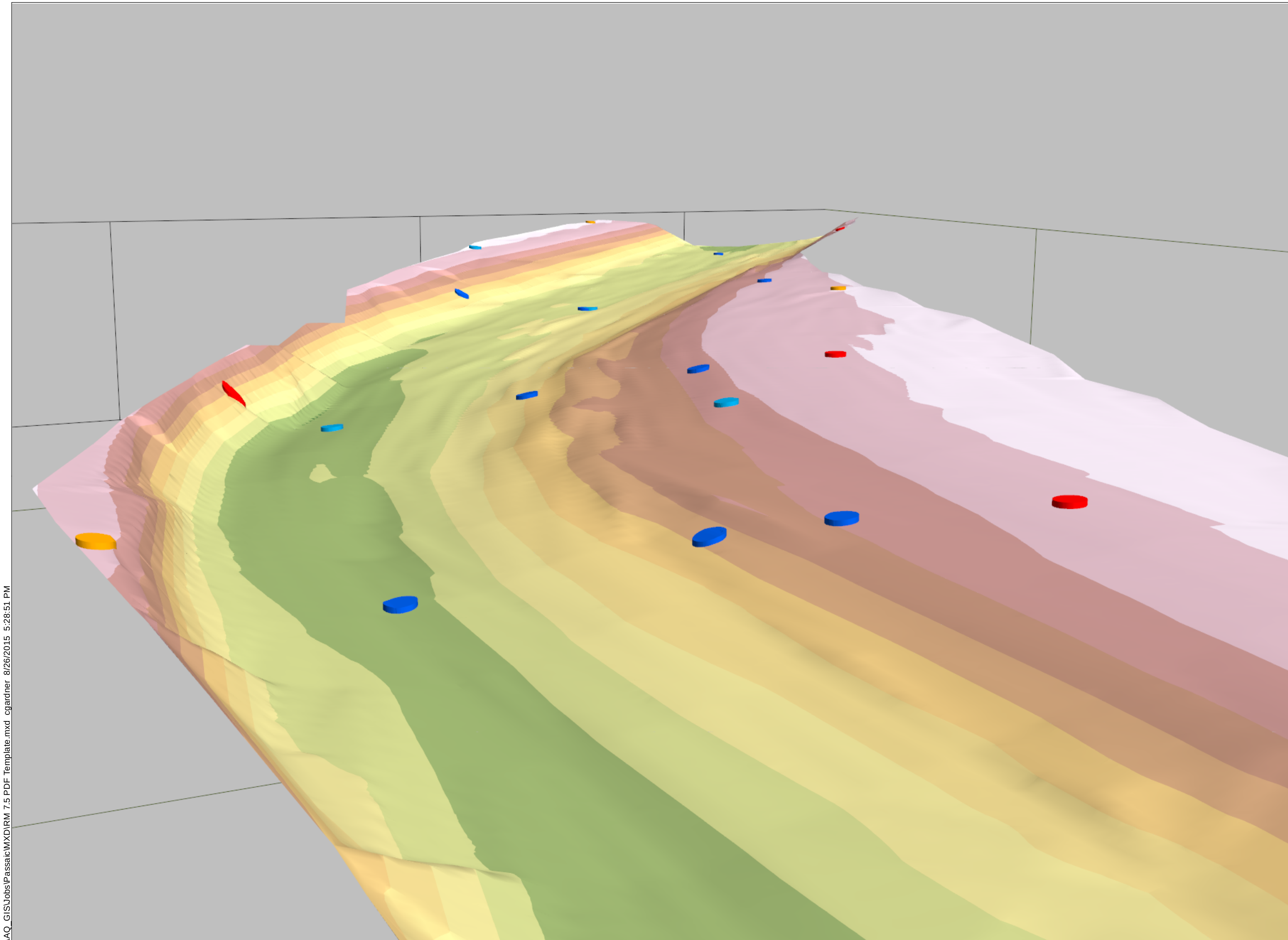
**Note:**
· Mudline elevations were not available for the samples appearing outside of the extent of the bathymetry. The base elevations for these samples have been arbitrarily established at +2 ft NGVD 29 to facilitate displaying them with the other samples in this figure.

**3D PDF Map Navigation Instructions:**
· Depress left mouse button + move mouse to rotate in all directions;
· Depress Ctrl button + left mouse button to pan;
· Rotate mouse wheel in/out to zoom in/out.

**Figure 2-5c**

2,3,7,8-TCDD Surface Sediment Concentrations over Bathymetry
Near RM 10.9 - View Top
Contaminant Mapping Response
Lower Passaic River Study Area Remedial Investigation/Feasibility Study



**Legend**

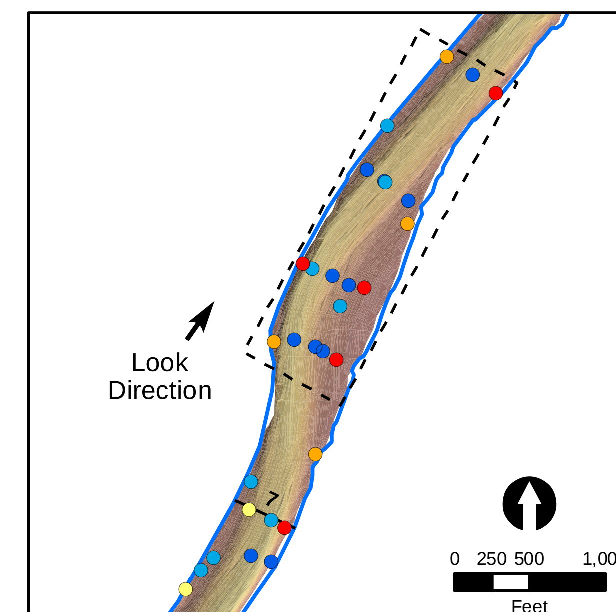
**2,3,7,8-TCDD**

**Concentrations (ng/kg)**

- 0 - 250
- 251 - 500
- 501 - 1,000
- 1,001 - 3,000
- 3,001 - 10,000
- > 10,000

**2004 Bathymetry in feet (NGVD29)**

- 0.1 - 2
- -1.9 - 0
- -3.9 - -2
- -5.9 - -4
- -7.9 - -6
- -9.9 - -8
- -11.9 - -10
- -13.9 - -12
- -15.9 - -14
- -17.9 - -16
- -19.7 - -18




Vertical Exaggeration: 3X

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**Figure 2-6**
2,3,7,8-TCDD Surface Sediment Concentrations over Bathymetry Near RM 7.5
Contaminant Mapping Response
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

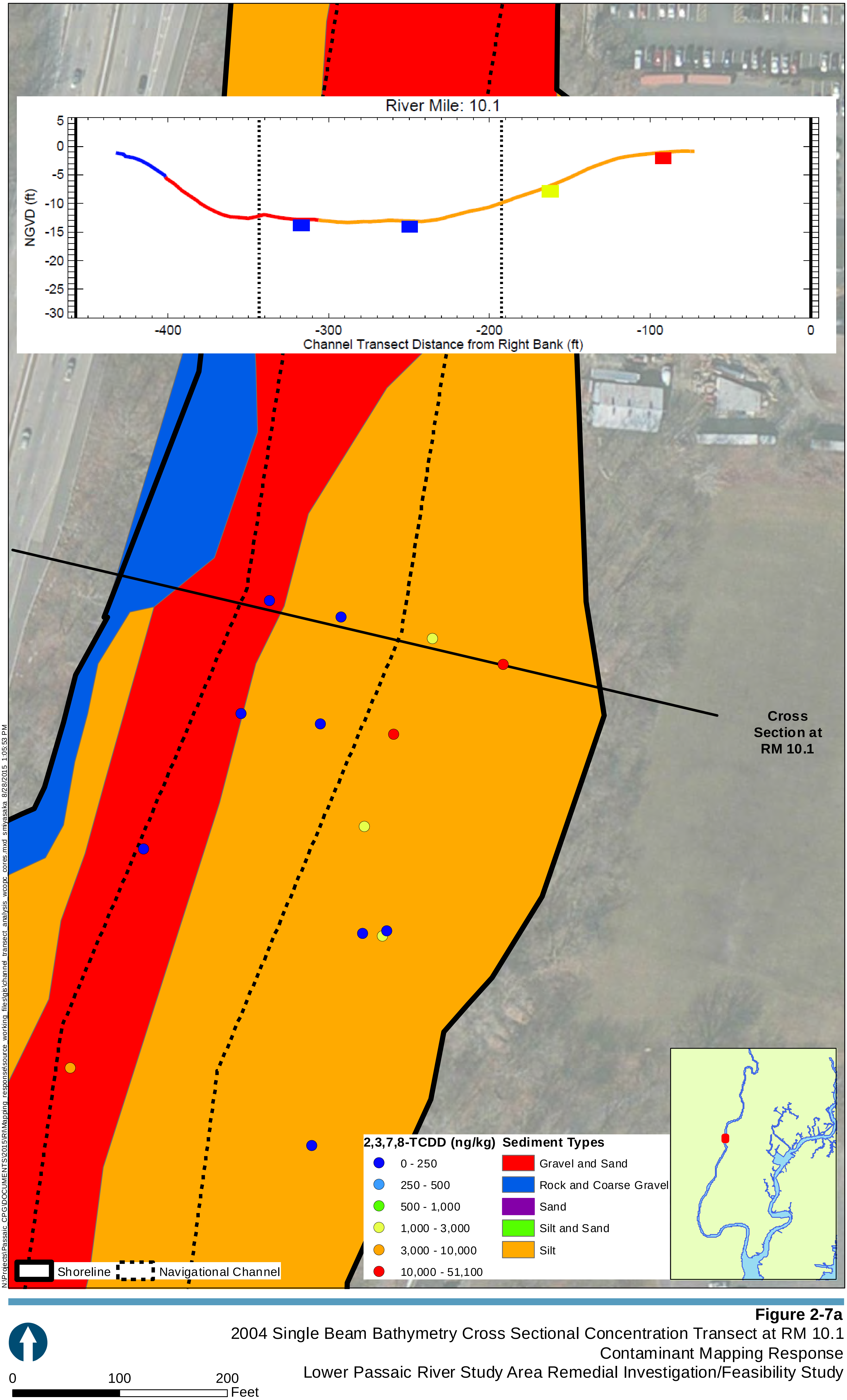
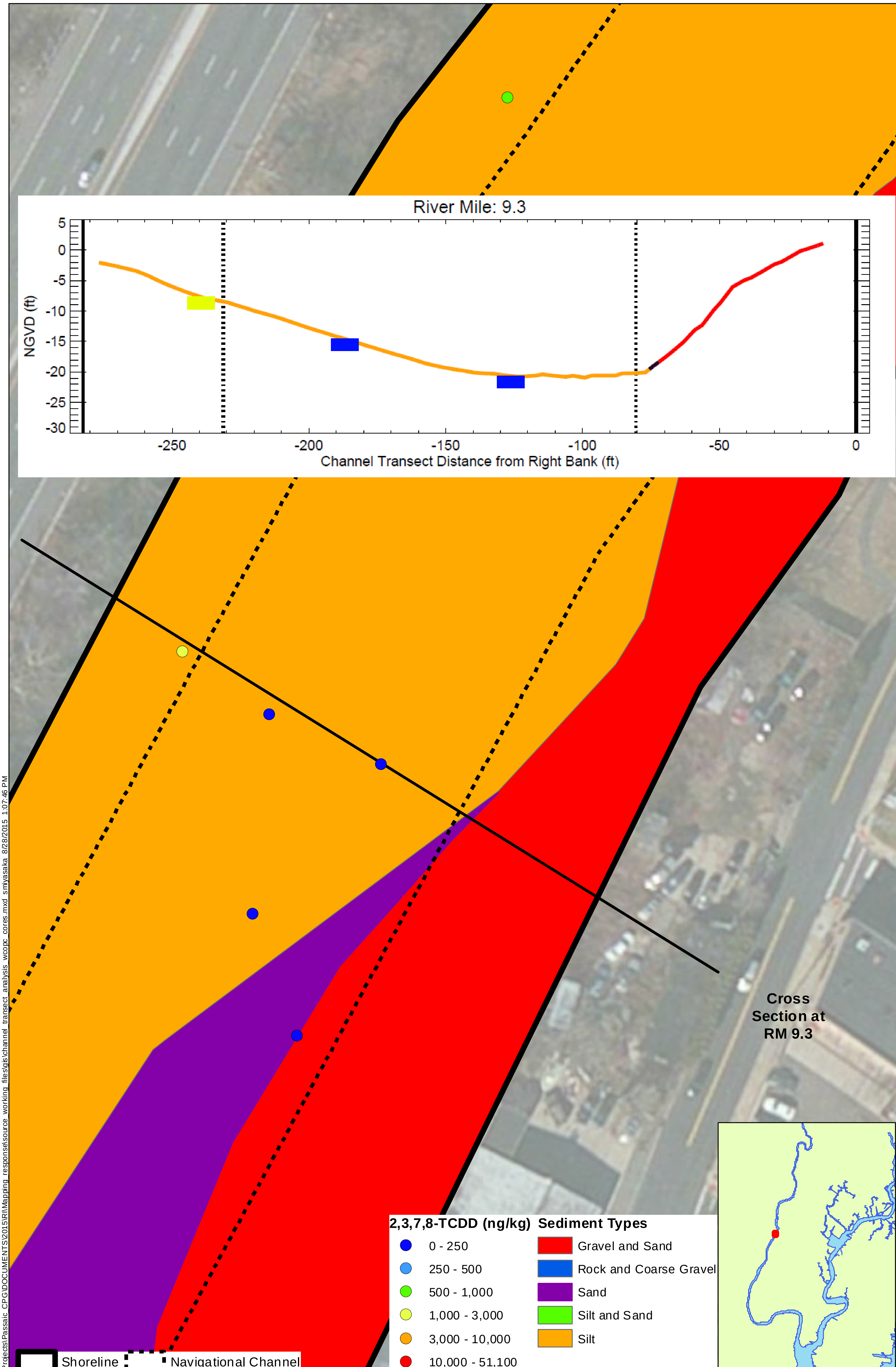



**Figure 2-7a**

2004 Single Beam Bathymetry Cross Sectional Concentration Transect at RM 10.1

Contaminant Mapping Response

Lower Passaic River Study Area Remedial Investigation/Feasibility Study





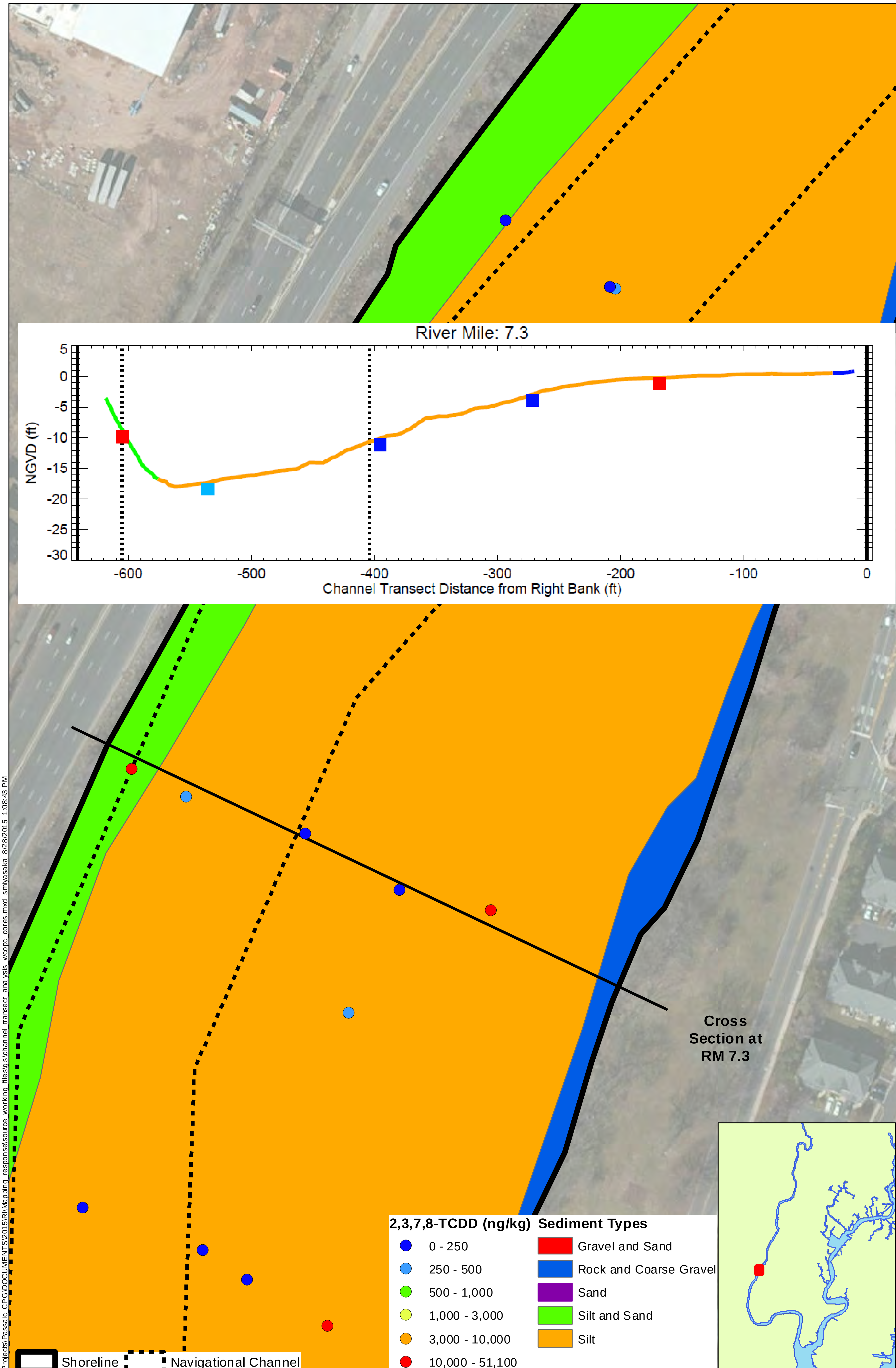

0 50 100
Feet

**Figure 2-7b**

2004 Single Beam Bathymetry Cross Sectional Concentration Transect at RM 9.3

Contaminant Mapping Response

Lower Passaic River Study Area Remedial Investigation/Feasibility Study



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Feet

**Figure 2-7c**

2004 Single Beam Bathymetry Cross Sectional Concentration Transect at RM 7.3

Contaminant Mapping Response

Lower Passaic River Study Area Remedial Investigation/Feasibility Study

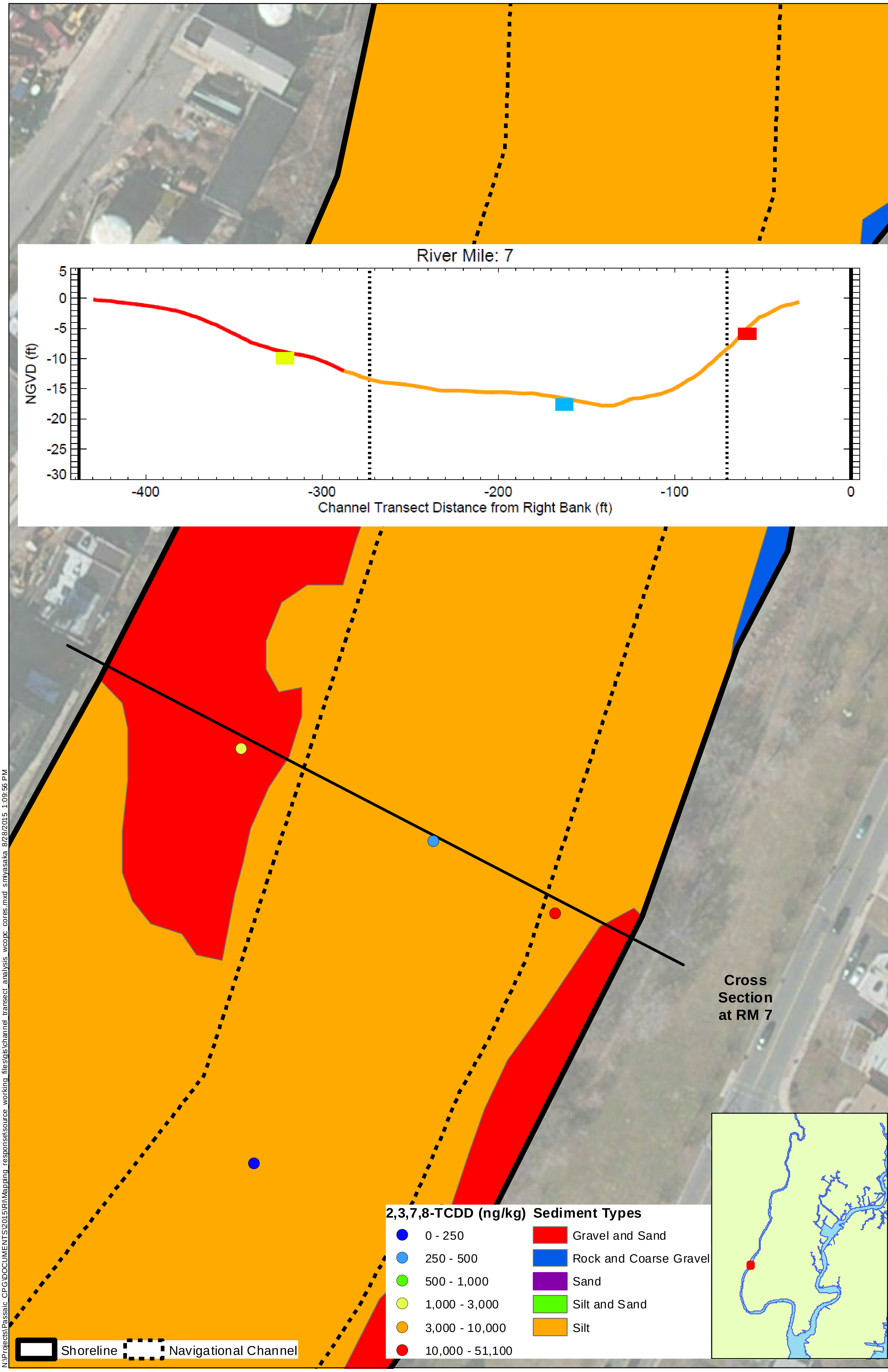


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**Figure 2-7d**

2004 Single Beam Bathymetry Cross Sectional Concentration Transect at RM 7

Contaminant Mapping Response

Lower Passaic River Study Area Remedial Investigation/Feasibility Study

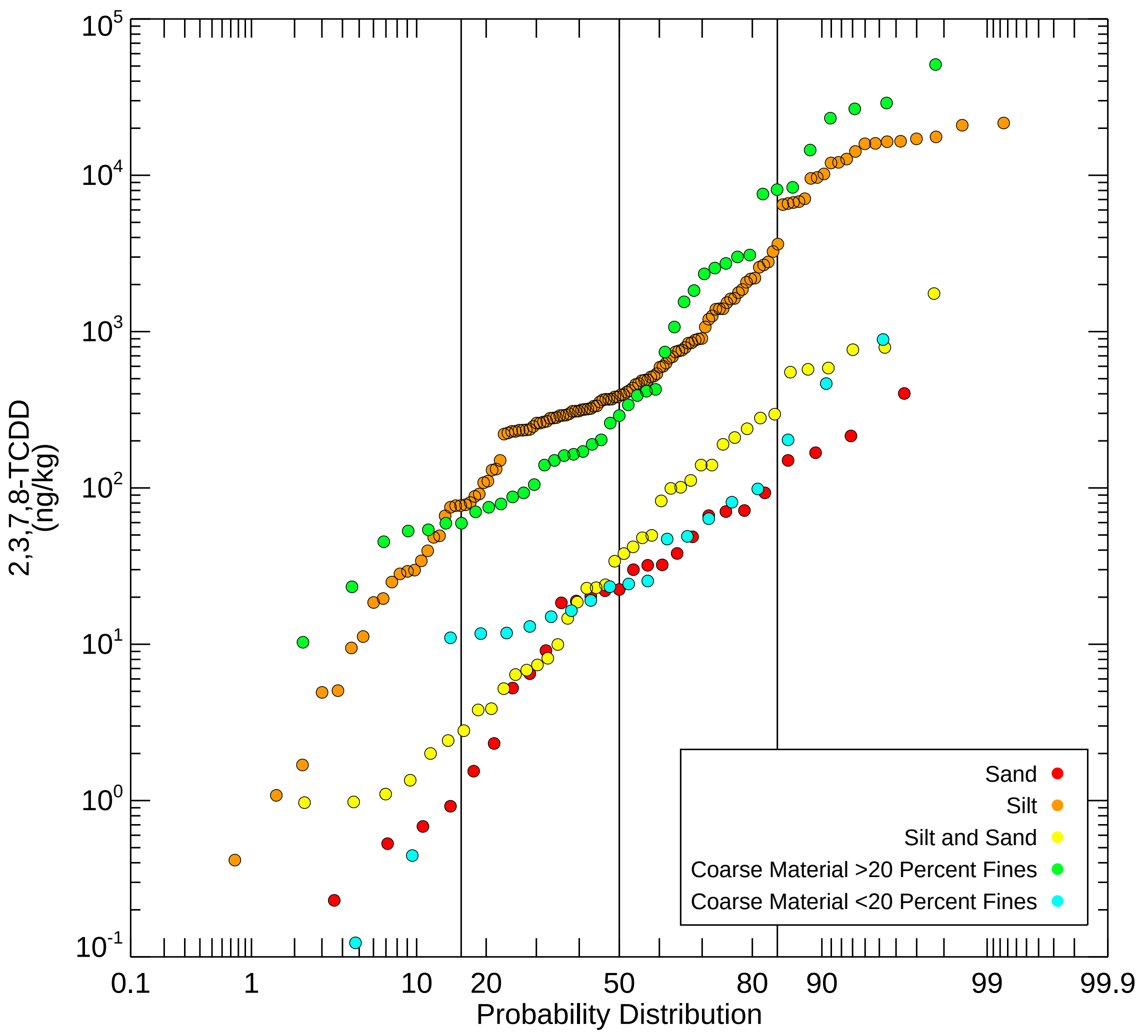


**Figure 2-8**

Distribution of Surface 2,3,7,8-TCDD Concentration by Sediment Type between RM 7.8 and 15
Contaminant Mapping Response
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

*Note: Includes data from 1995-2013. Data between RM 7.8 and 15.*
*Sediment types from the 2005 Side Scan Sonar Survey with expanded silt delineations from more recent probing and sample data.*

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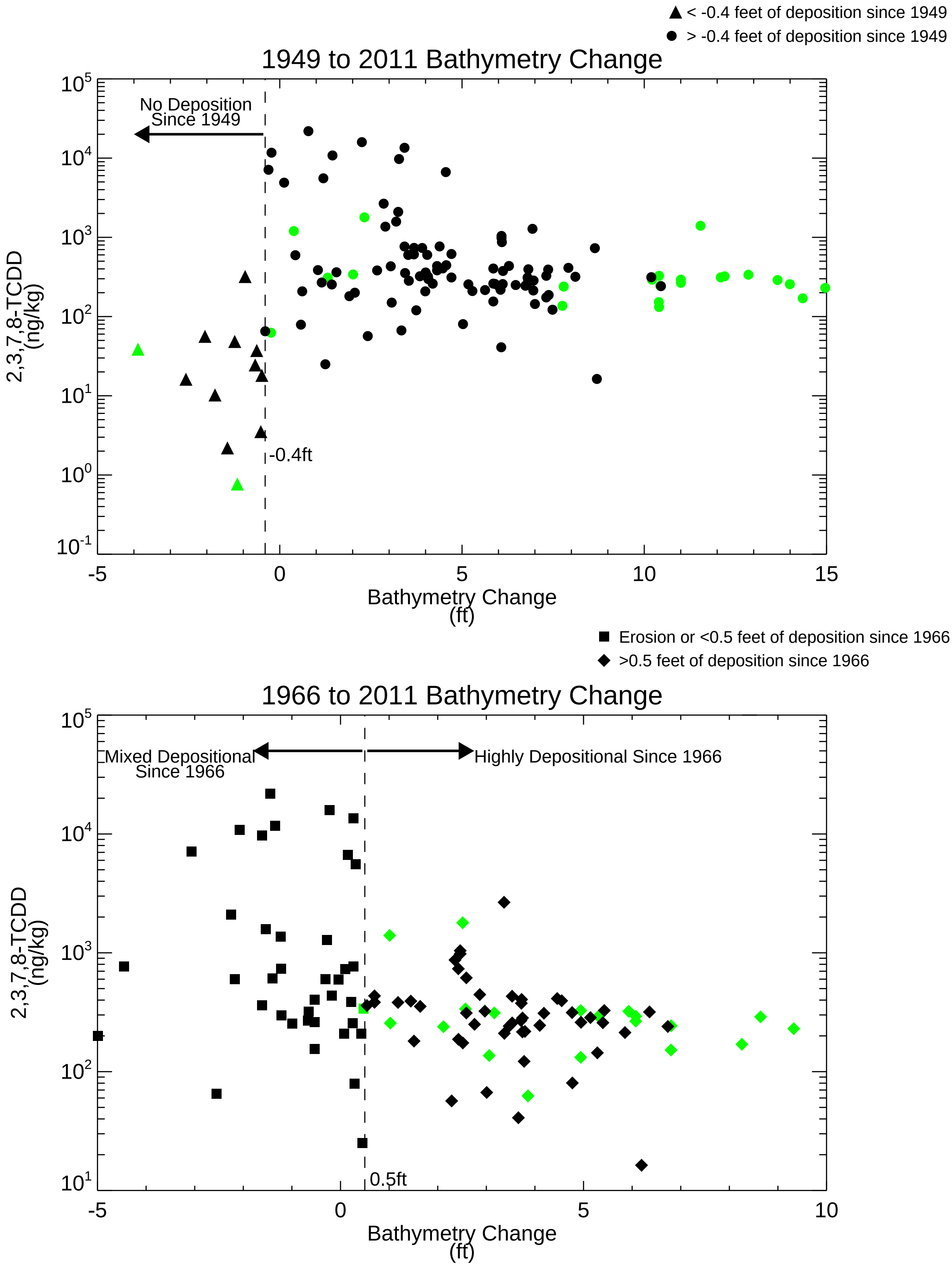


● Channel (Non-Shoal)
● Shoal

**Figure 2-9**

2,3,7,8-TCDD Surface Concentration Versus Bathymetry Change
Contaminant Mapping Response
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

*Includes data from 1995-2013* between RM 2.4-6.8.
*Only data with greater than -0.4ft deposition since 1949 are plotted on the second panel.*

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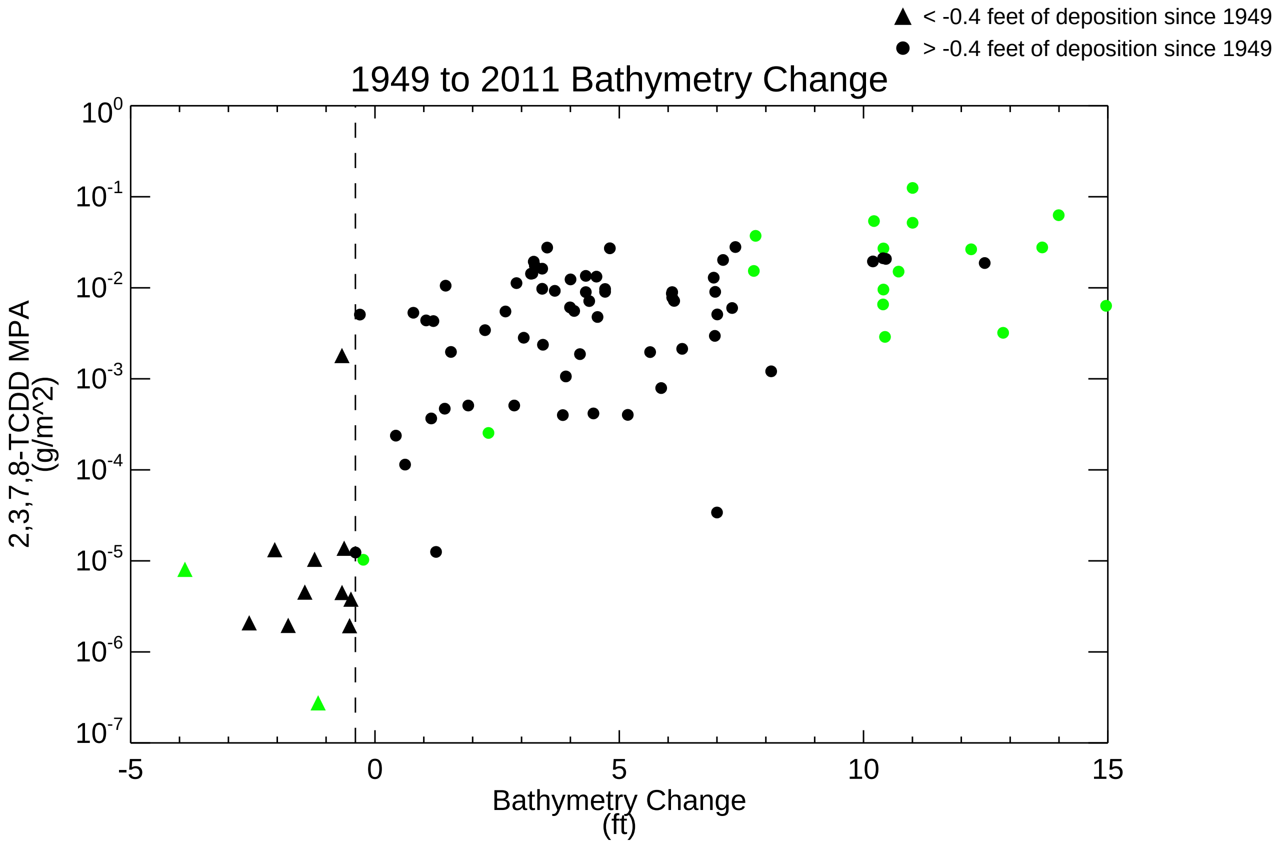


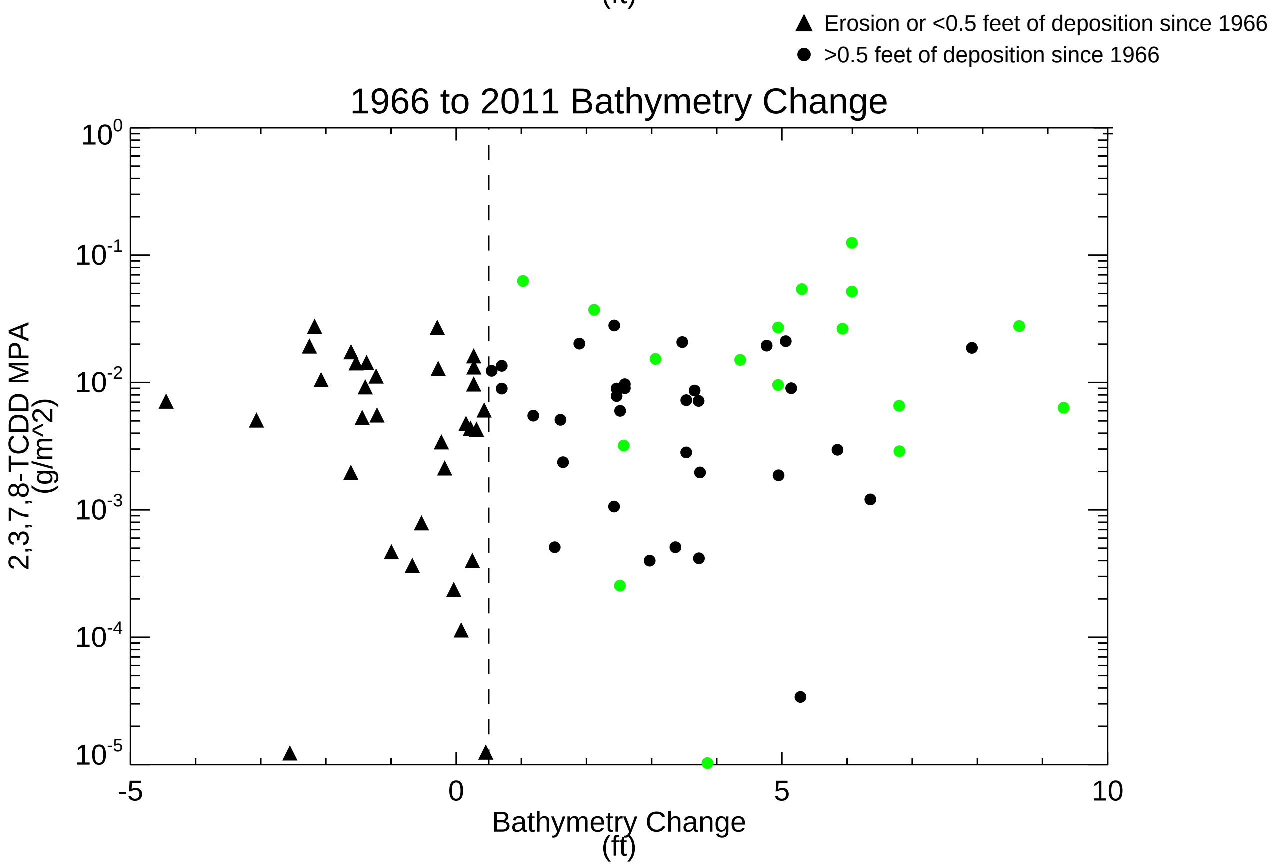


**Figure 2-10**

● Channel (Non-Shoal)
● Shoal

2,3,7,8-TCDD MPA Versus Bathymetry Change
Contaminant Mapping Response
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

*Data are from RM 2.4-6.8. Only data with greater than -0.4ft deposition since 1949 are plotted on the second panel.*

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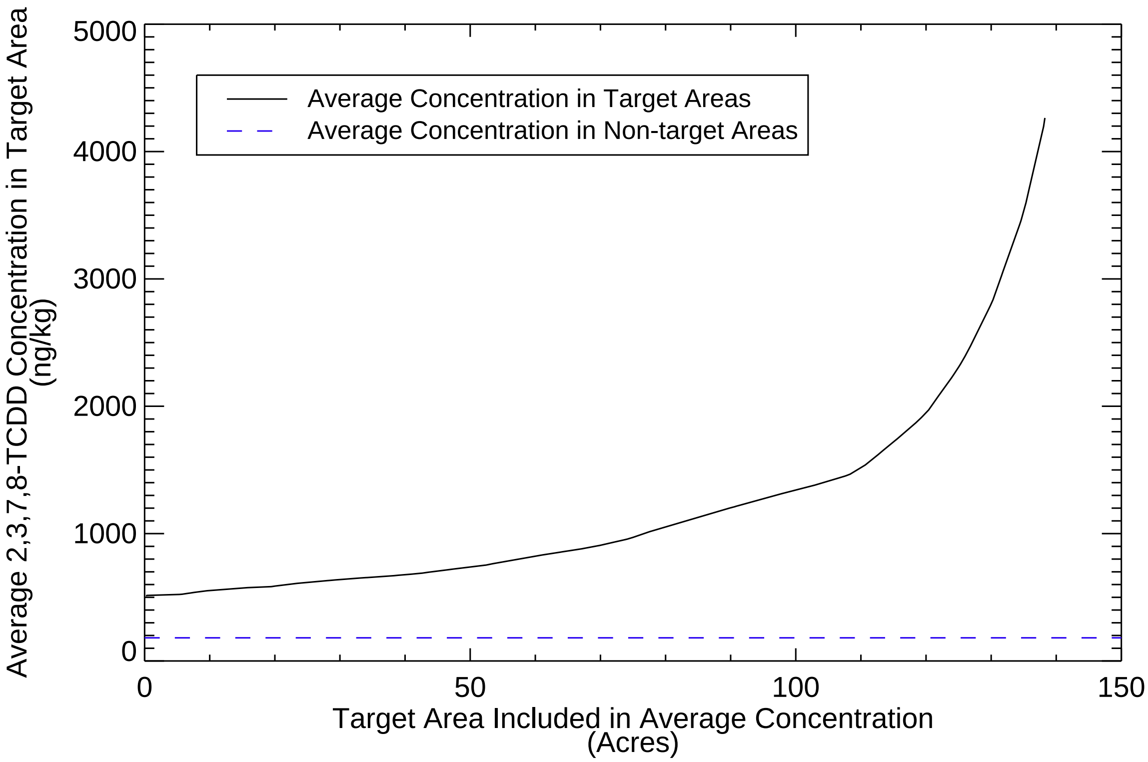


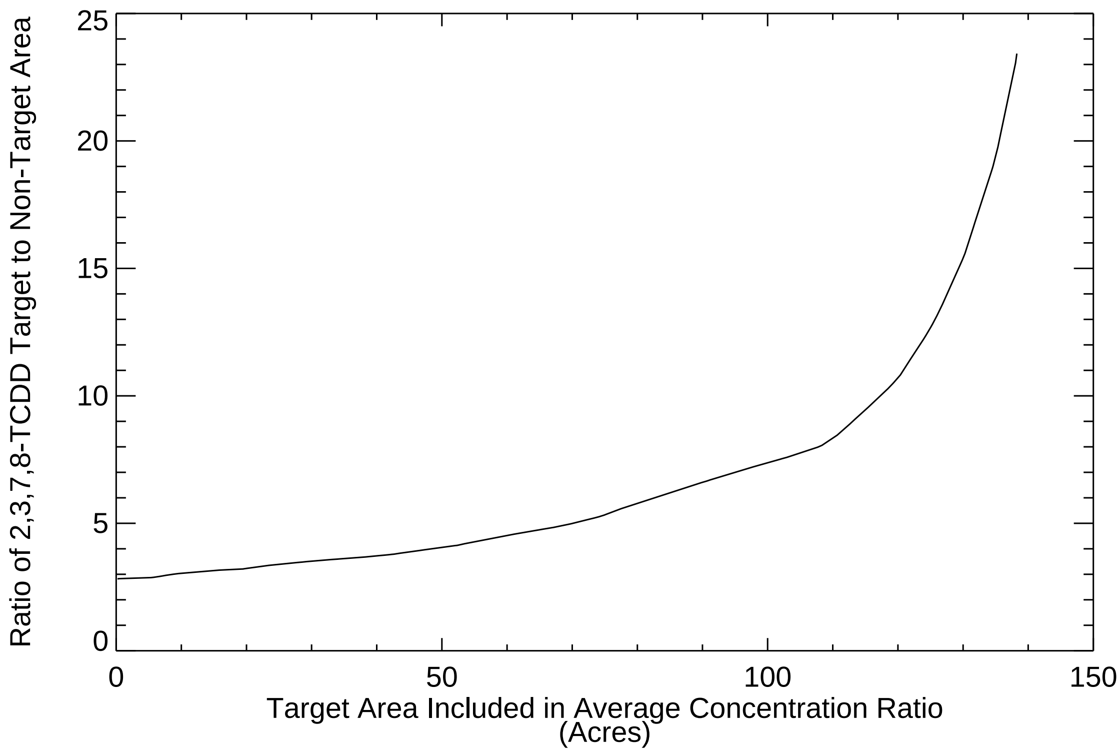


**Figure 3-1**

Influence of Target Areas on Average 2,3,7,8-TCDD Concentration
Contaminant Mapping Response
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

*Only include polygons with concentrations >=500.*
*Excludes ph1, ph2, and RM 10.9 (assumes already remediated to zero).*
*Horizontal line at 182 is the average concentration in non-target areas between RM 0-14.7.*

sm - \\cambridge2\jobs\Passaic_CPG\ANALYSIS\Sed_Char\Interpolations\b20150123_edit_shoal\IDL_code\cpgpas_conc_ratio_vs_rem_area.pro
Mon Oct 05 13:29:28 2015

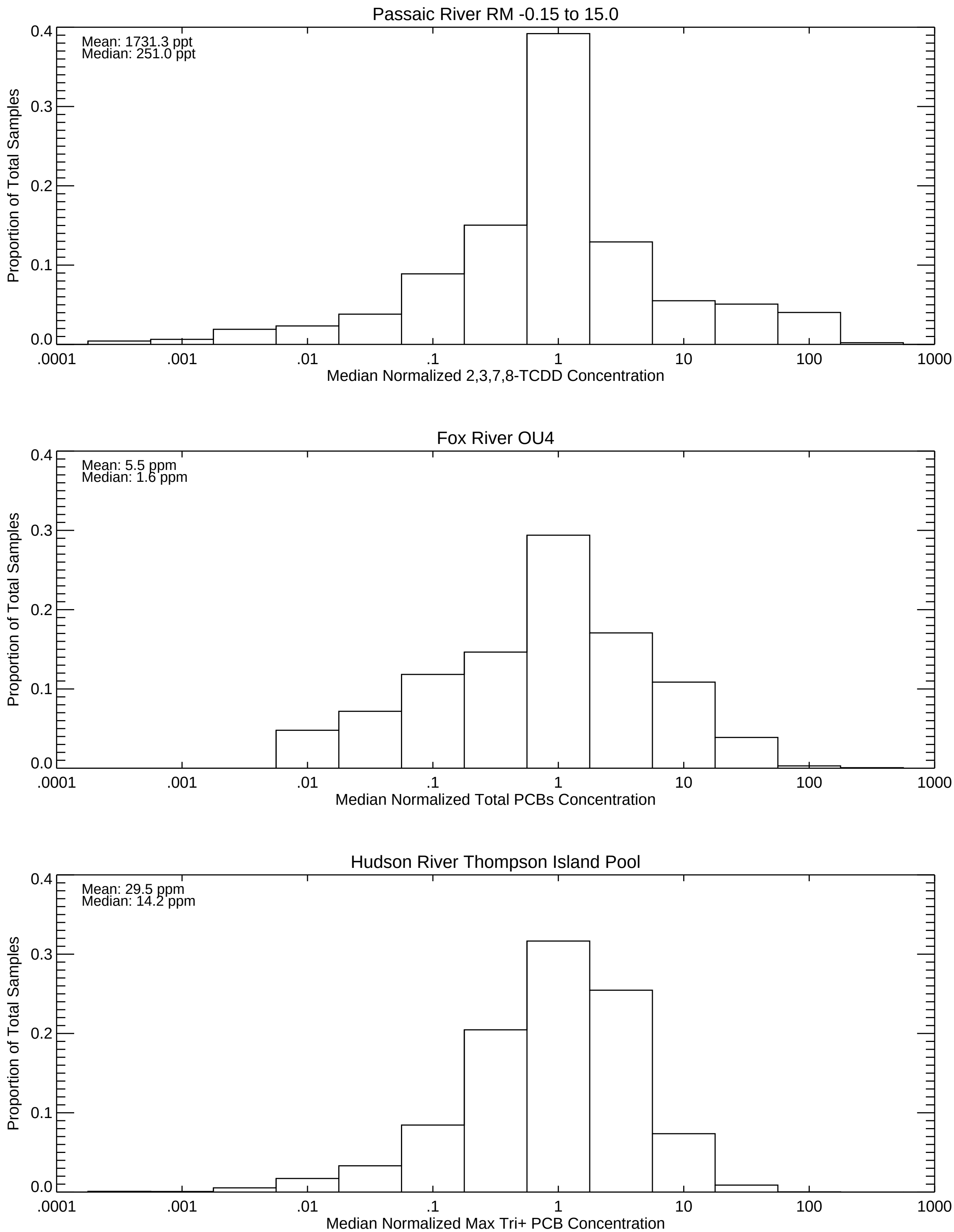


**Figure 3-2**

Histograms of Surface Sediment Contaminant Concentration for Several Rivers
Contaminant Mapping Response
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

*Note: Passaic data from 2005-2013.*

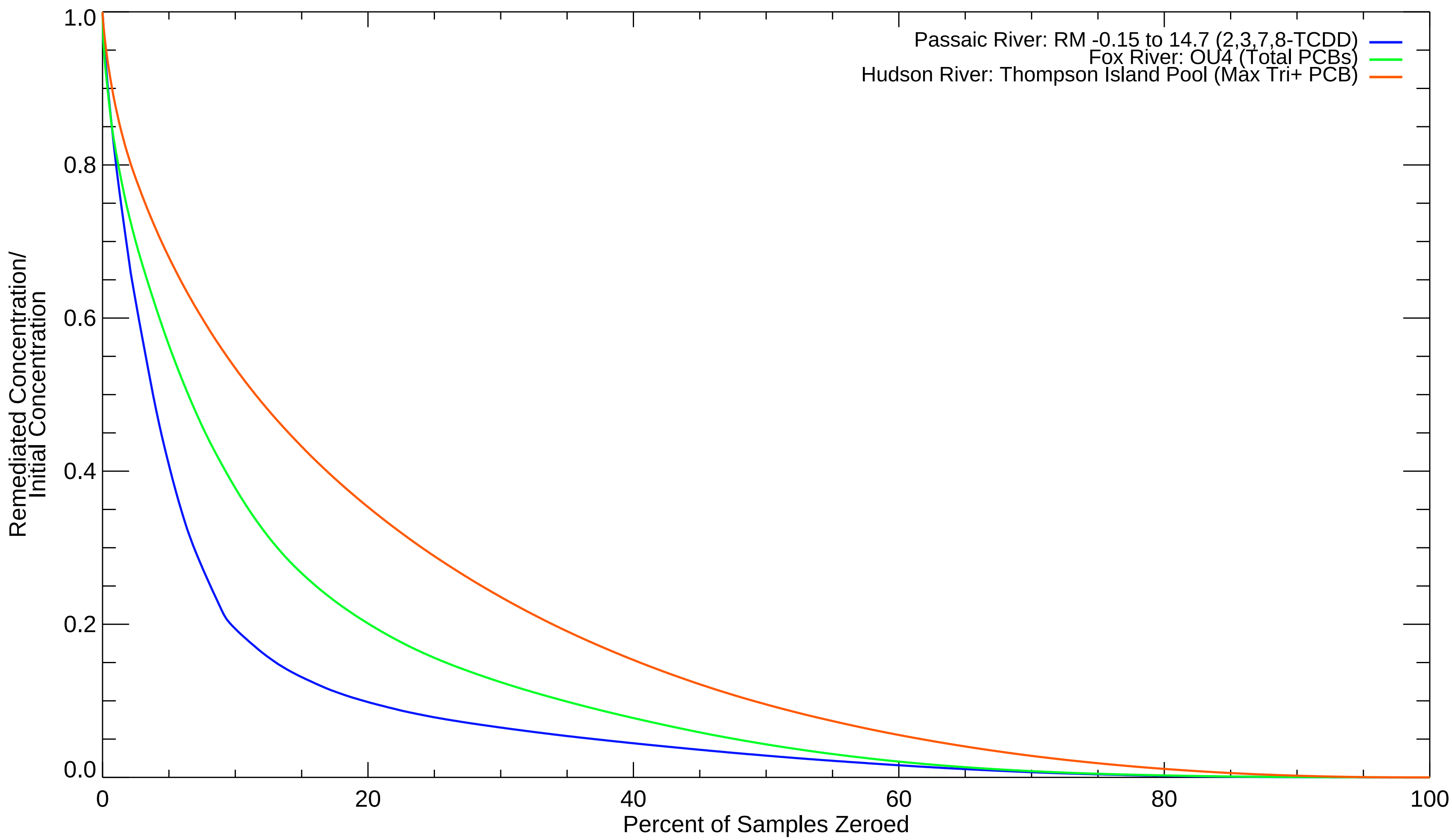


**Figure 3-3**

Conceptual Remediation Curves of Surface Sediment Contaminant Concentration for Several Rivers

Contaminant Mapping Response

Lower Passaic River Study Area Remedial Investigation/Feasibility Study

*Note: Passaic data from 2005-2013.*

GD - H:\Passaic_CPG\DOCUMENTS\2015\RI_Report\Mapping_response\source_working_files\pascpg_RemediationCurve_20150929.pro
Mon Oct 05 14:23:54 2015

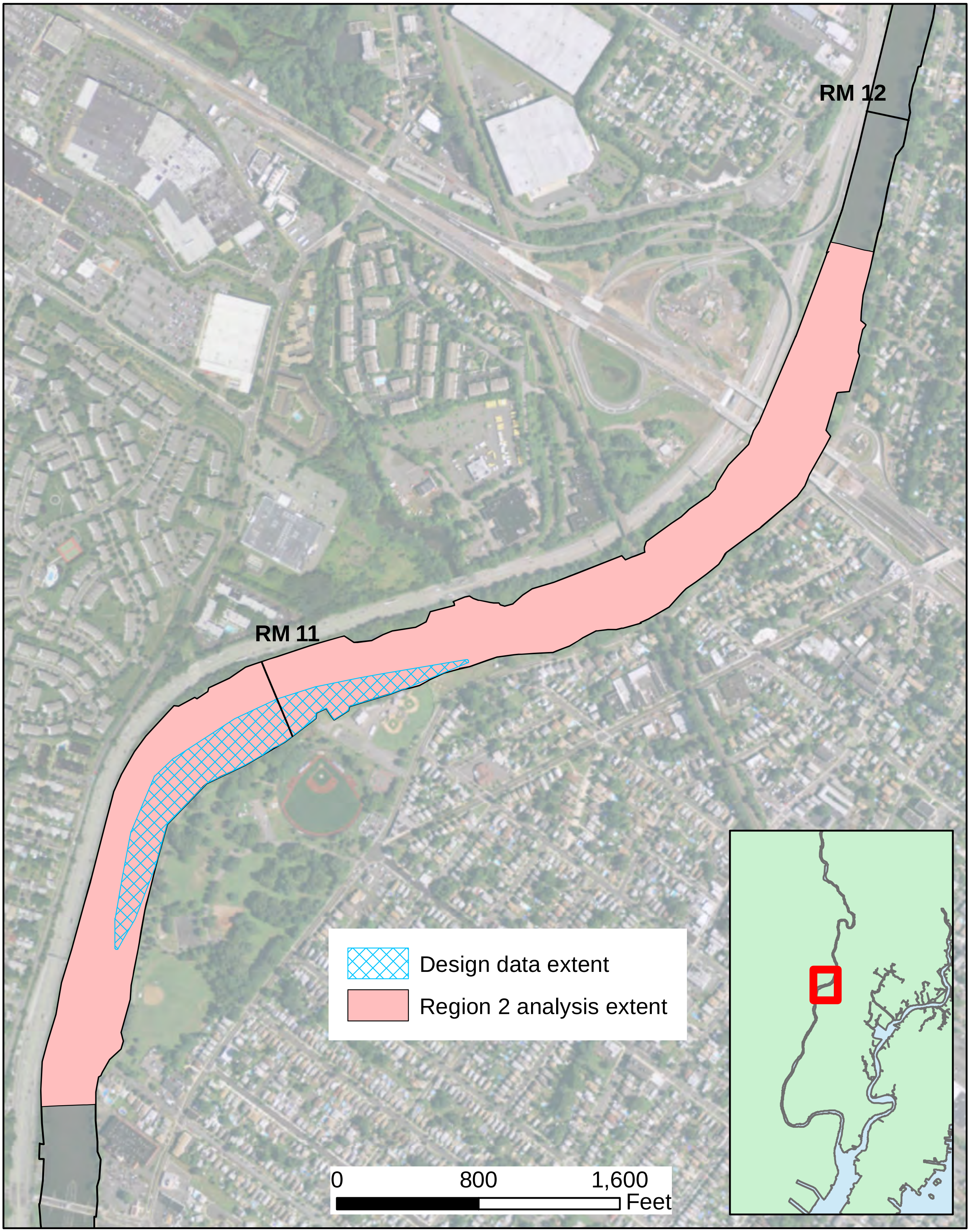


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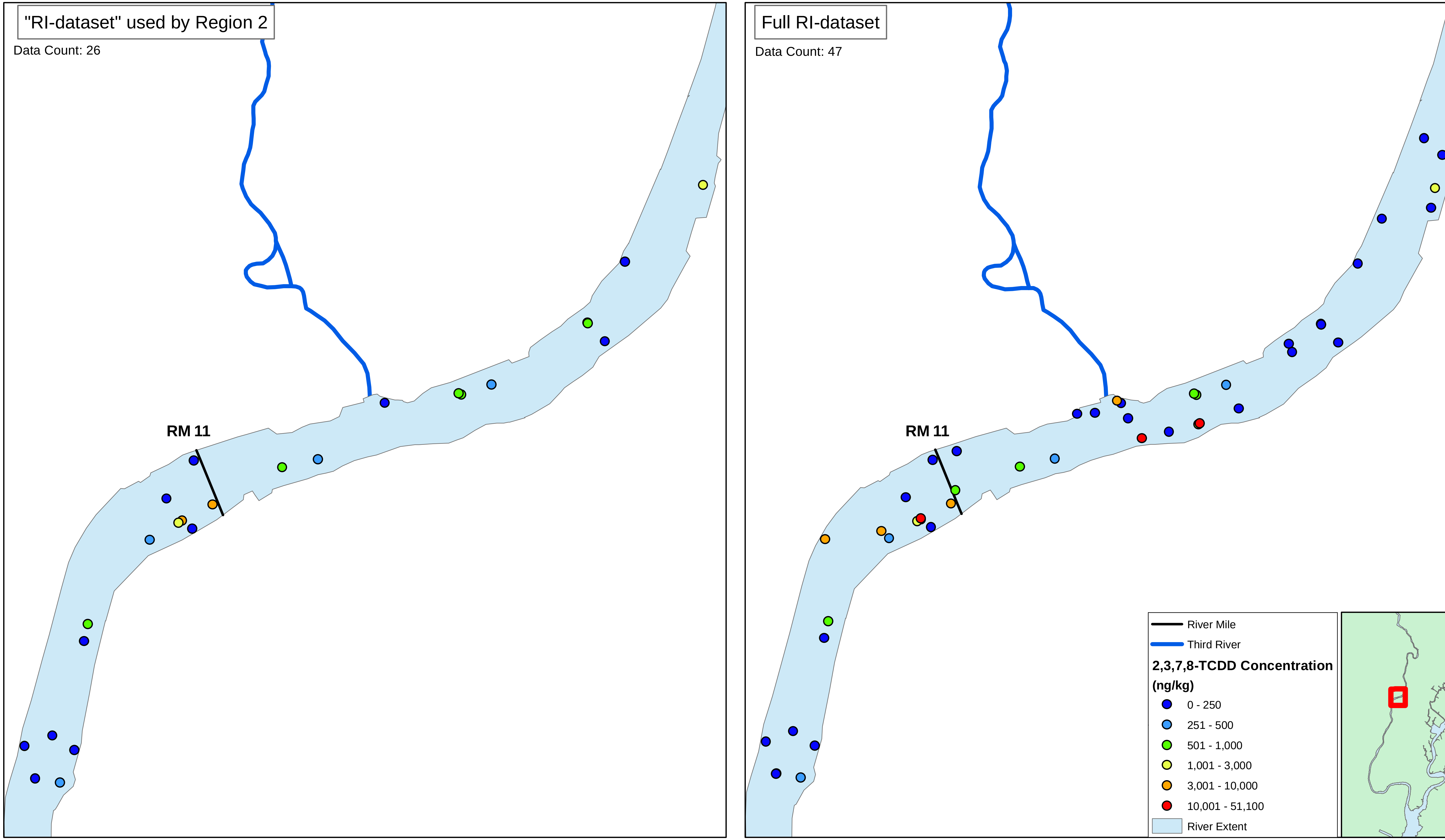
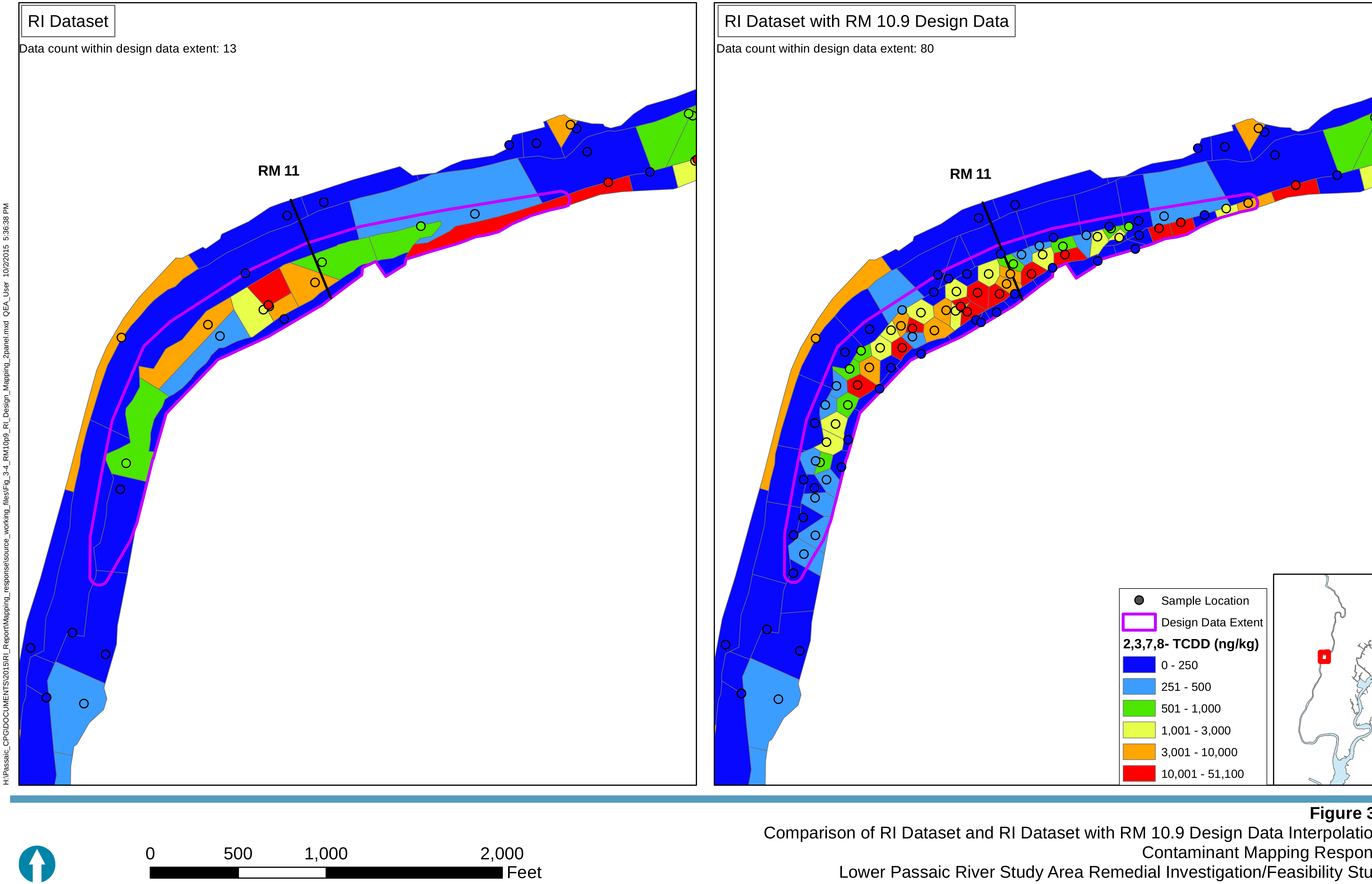
**Figure 3-4**
Extent of RM10.9 Design Data within Region 2 Analysis Extent
Contaminant Mapping Response
Lower Passaic River Study Area Remedial Investigation/Feasibility Study




0 0.1 0.2 0.4
Miles

**Figure 3-5**
Comparison of RI-dataset Used by Region 2 With Full RI Dataset Near RM 10.9
Contaminant Mapping Response
Lower Passaic River Study Area Remedial Investigation/Feasibility Study



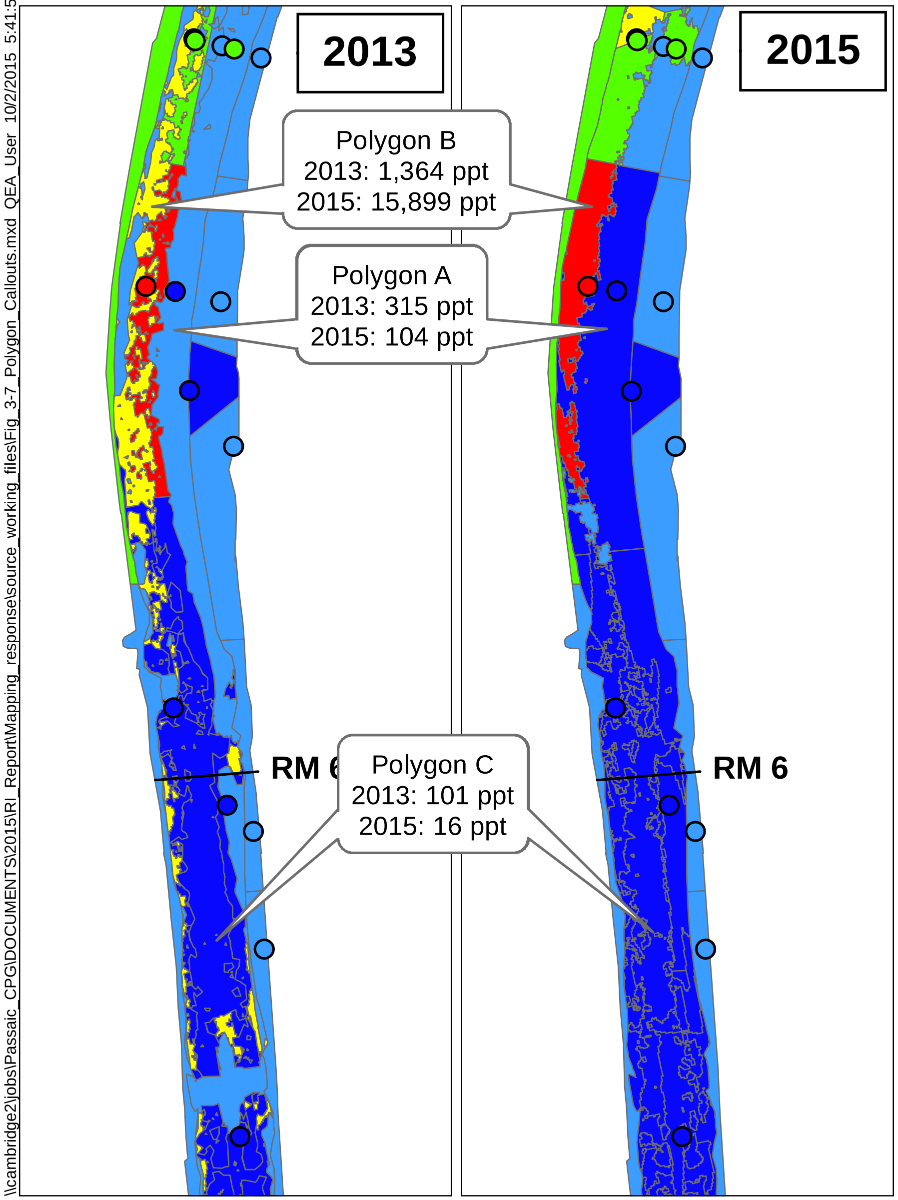

H:\Passaic_CPG\DOCUMENTS\2015\RI_Report\Mapping_response\source_working_files\Fig_3-4_RM10p9_RI_Design_Mapping_2panel.mxd QEA_User 10/2/2015 5:36:38 PM

**Figure 3-6**

Comparison of RI Dataset and RI Dataset with RM 10.9 Design Data Interpolations

Contaminant Mapping Response

Lower Passaic River Study Area Remedial Investigation/Feasibility Study




## Polygon A

- 2013 used average of data in highly depositional channel areas between RM 1.5-7.5.
- 2015 uses Thiessen polygon interpolation.

## Polygon B

- 2013 split mixed depositional channel areas into two groups (Groups 3a and 3b).
- 2015 simplified the area as a single mixed depositional grouping.
- For the 2013 mapping, an upstream sample interpolated into this polygon. This does not occur in 2015 due to greater data density with Groups 3a and 3b combined.

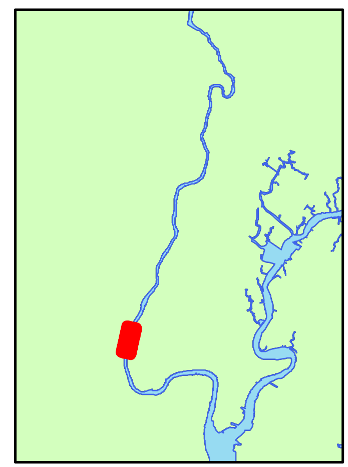
## Polygon C

- 2013 used average of data in non-depositional channel areas between RM 1.5-7.5.
- 2015 uses Thiessen Polygon interpolation.

Sample Location

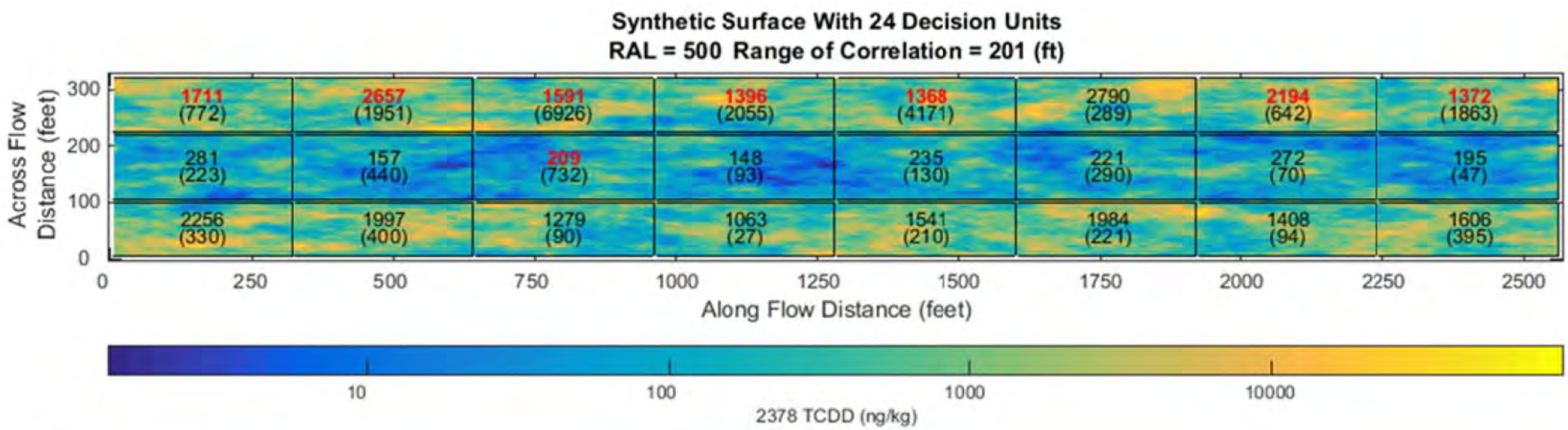
**2,3,7,8-TCDD Conc. (ng/kg)**

0 - 250
251 - 500
501 - 1000
1001 - 3000
3001 - 10000
100001 - 51100



0 600 1,200 Feet

**Figure 3-7**
Explanation of Differences Between 2013 and 2015 Mapping that were Identified by Region 2
Contaminant Mapping Response
Lower Passaic River Study Area Remedial Investigation/Feasibility Study




Notes:

1) Decision unit average represented by top number: 2256

2) Single sample value shown in parentheses: (330)

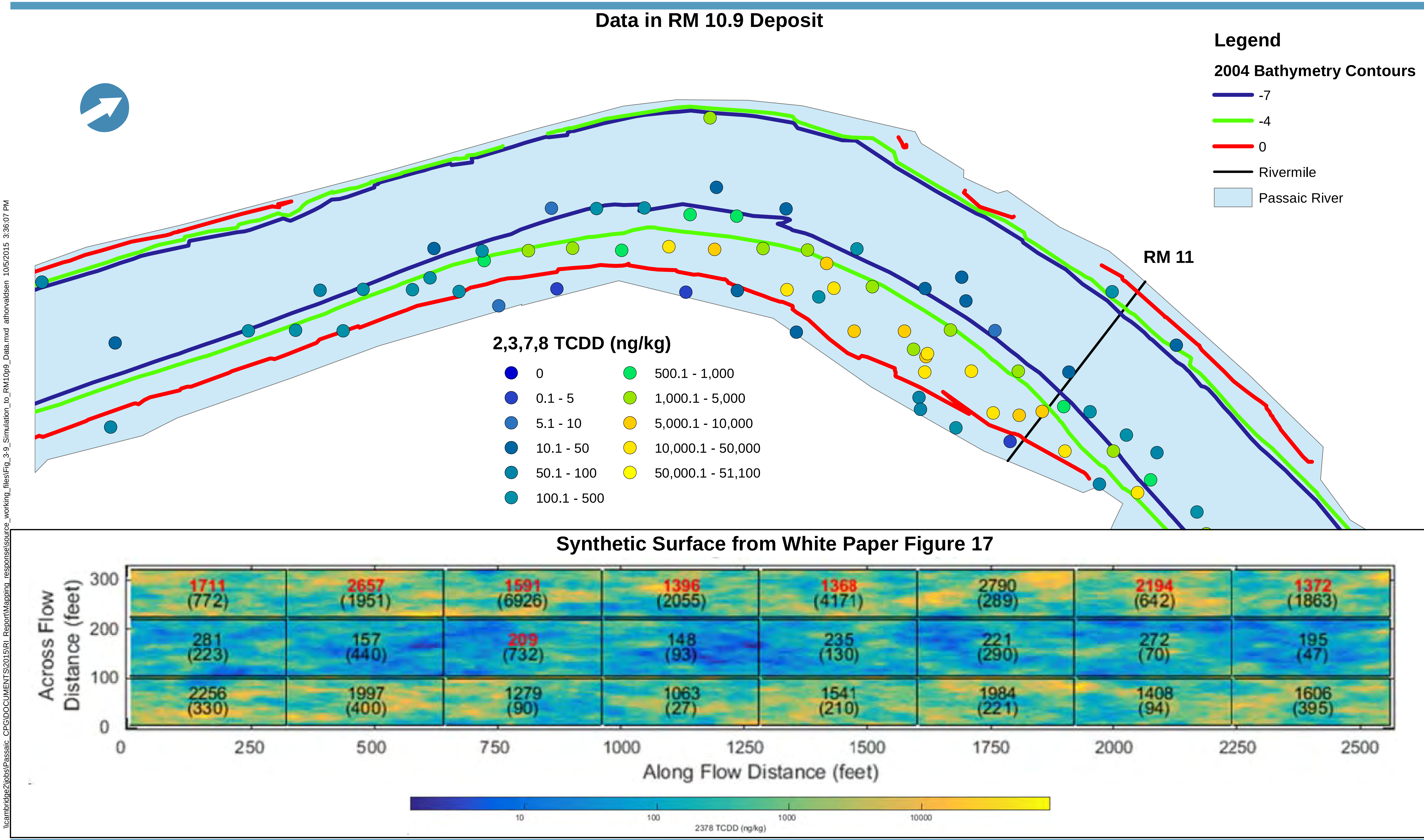
3) Red text indicates cells identified for removal because the sample value exceeds the RAL = 500

**Figure 3-8**

Region 2 Synthetic Surface from White Paper Figure 17

Contaminant Mapping Response

Lower Passaic River Study Area Remedial Investigation/Feasibility Study




0 200 400 800 1,200 1,600 Feet

**Figure 3-9**
Region 2 White Paper Simulation Results and RM 10.9 Data
Contaminant Mapping Response
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

\\cambridge2\jobs\Passaic_CPG\DOCUMENTS\2015\RI_Report\Mapping_response\source_working_files\Fig_3-9_Simulation_to_RM10p9_Data.mxd athorvaldsen 10/5/2015 3:36:07 PM

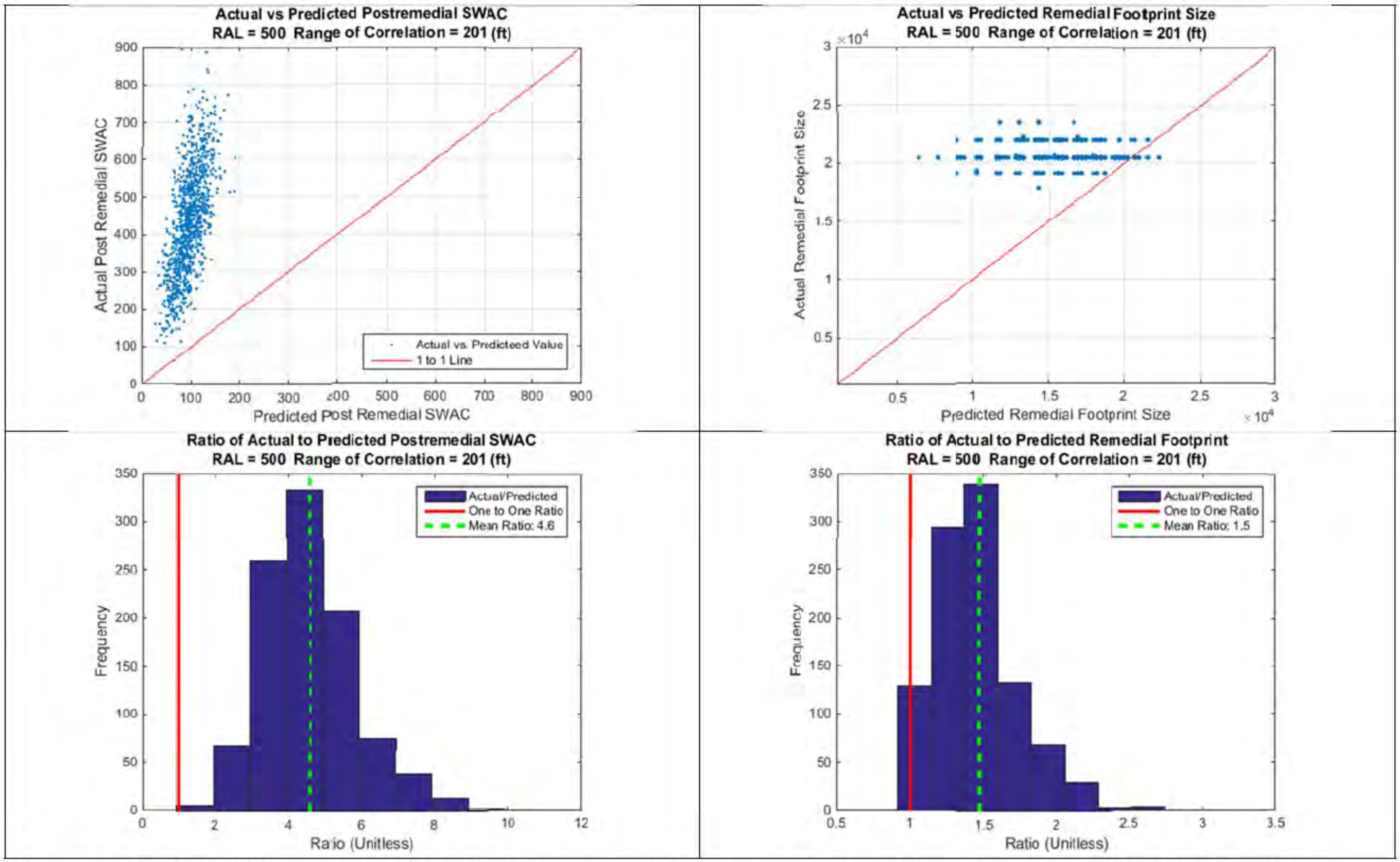



Figure 19. Actual vs predicted post-remedial SWAC (upper left panel ) and remedial footprint size (upper right panel) and ratio of actual to predicted post-remedial SWAC (lower left panel) and remedial footprint size (lower right panel) for 1000 synthetic 2,3,7,8-TCDD realizations subjected to the hill-topping algorithm used to develop the 500 ng/kg RAL proposed by the CPG.

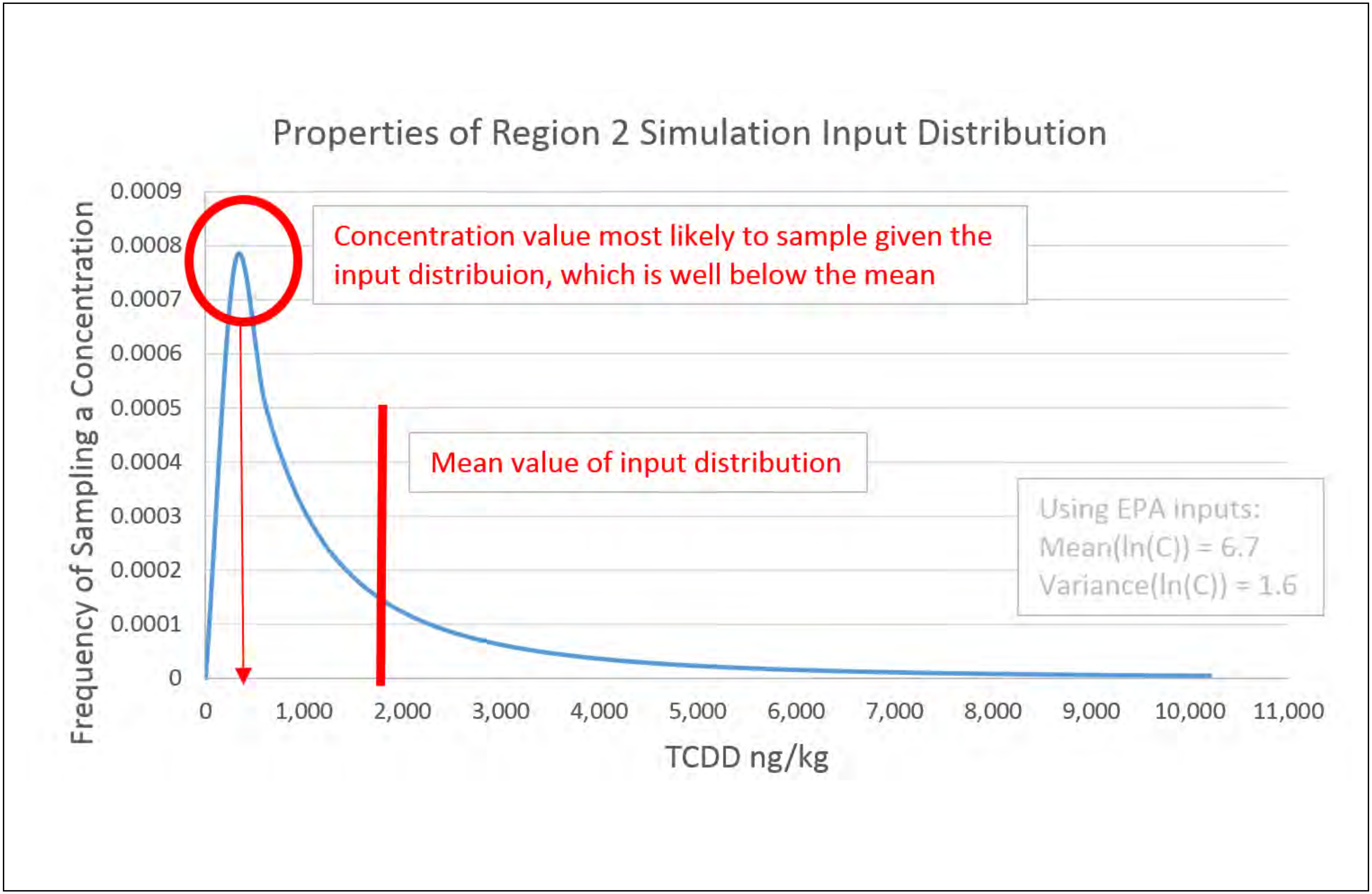
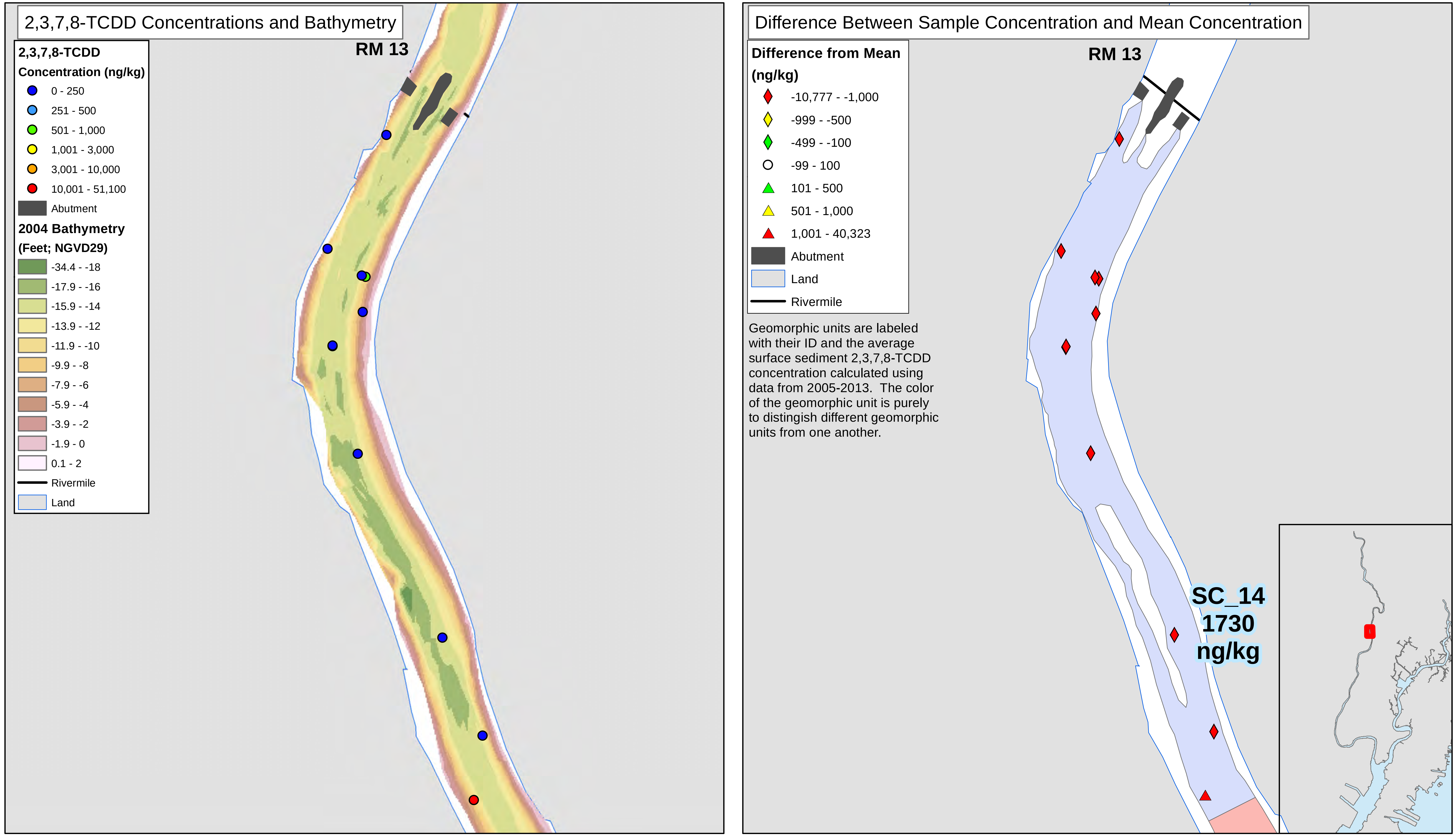



**Figure 3-11**
Properties of White Paper Simulation Input Distribution
Contaminant Mapping Response
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

*The plotted distribution reflects one of three input distributions used in the White Paper*




0 500 1,000
Feet

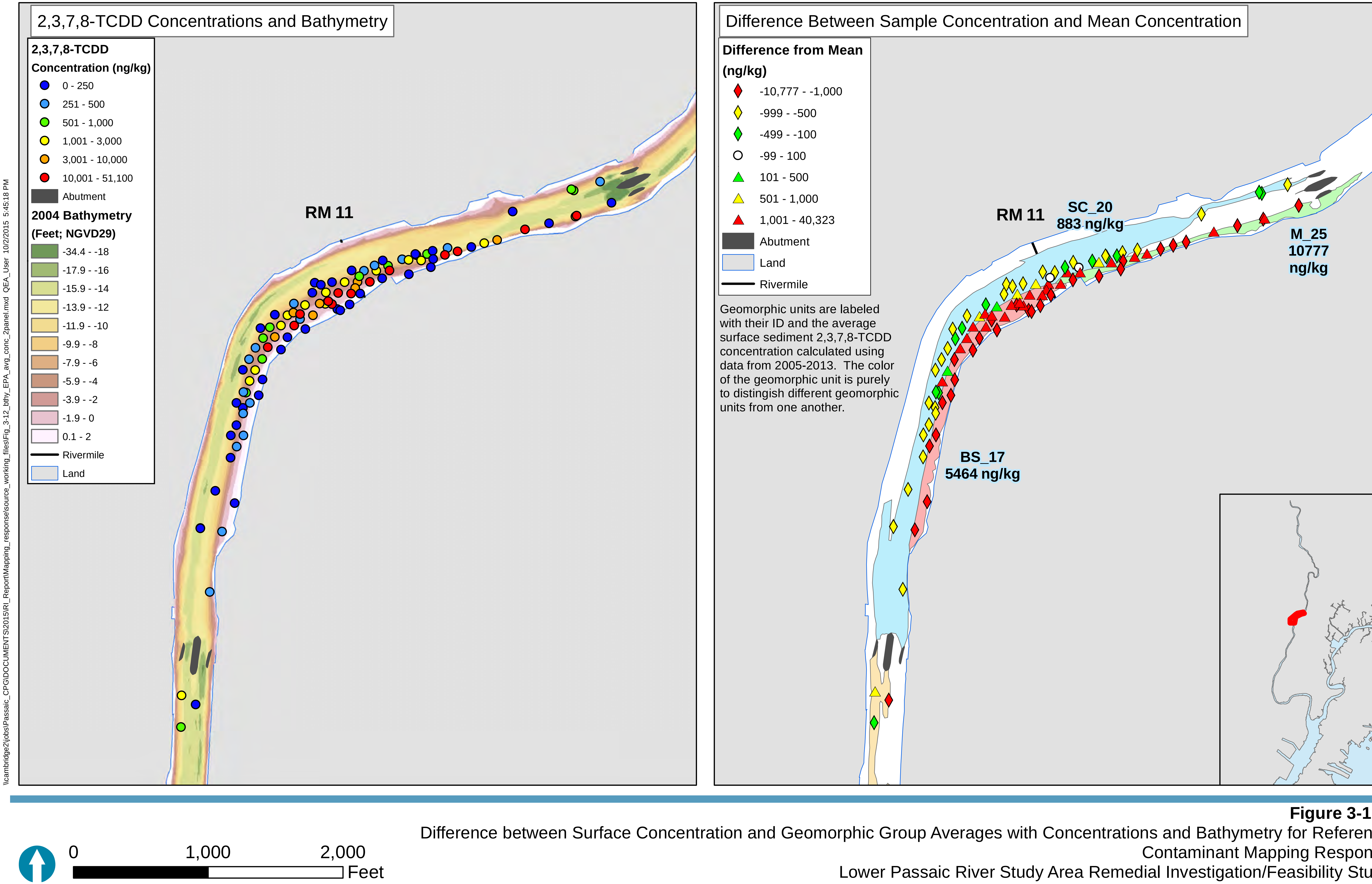
**Figure 3-12a**

Difference between Surface Concentration and Geomorphic Group Averages with Concentrations and Bathymetry for Reference

Contaminant Mapping Response

Lower Passaic River Study Area Remedial Investigation/Feasibility Study

\\cambridge2\jobs\Passaic_CPG\DOCUMENTS\2015\RI_Report\Mapping_response\source_working_files\Fig_3-12_bthy_EPA_avg_conc_2panel.mxd QEA_User 10/2/2015 5:45:13 PM




\\cambridge2\jobs\Passaic_CPG\DOCUMENTS\2015\RI_Report\Mapping_response\source_working_files\Fig_3-12_bthy_EPA_avg_conc_2panel.mxd QEA_User 10/2/2015 5:45:18 PM

**Figure 3-12b**

Difference between Surface Concentration and Geomorphic Group Averages with Concentrations and Bathymetry for Reference

Contaminant Mapping Response

Lower Passaic River Study Area Remedial Investigation/Feasibility Study

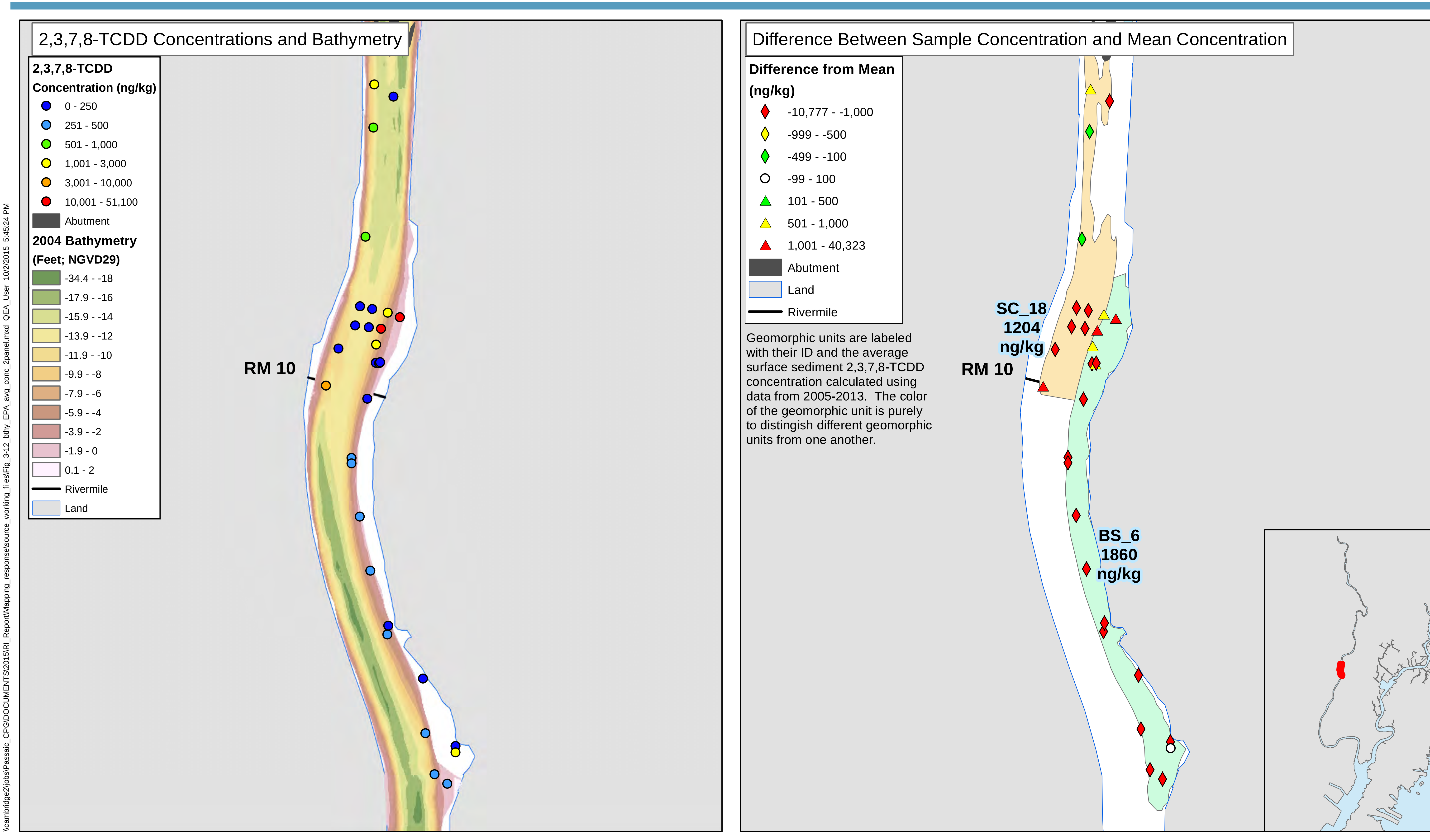


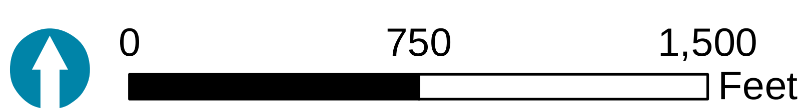



**Figure 3-12c**

Difference between Surface Concentration and Geomorphic Group Averages with Concentrations and Bathymetry for Reference

Contaminant Mapping Response

Lower Passaic River Study Area Remedial Investigation/Feasibility Study



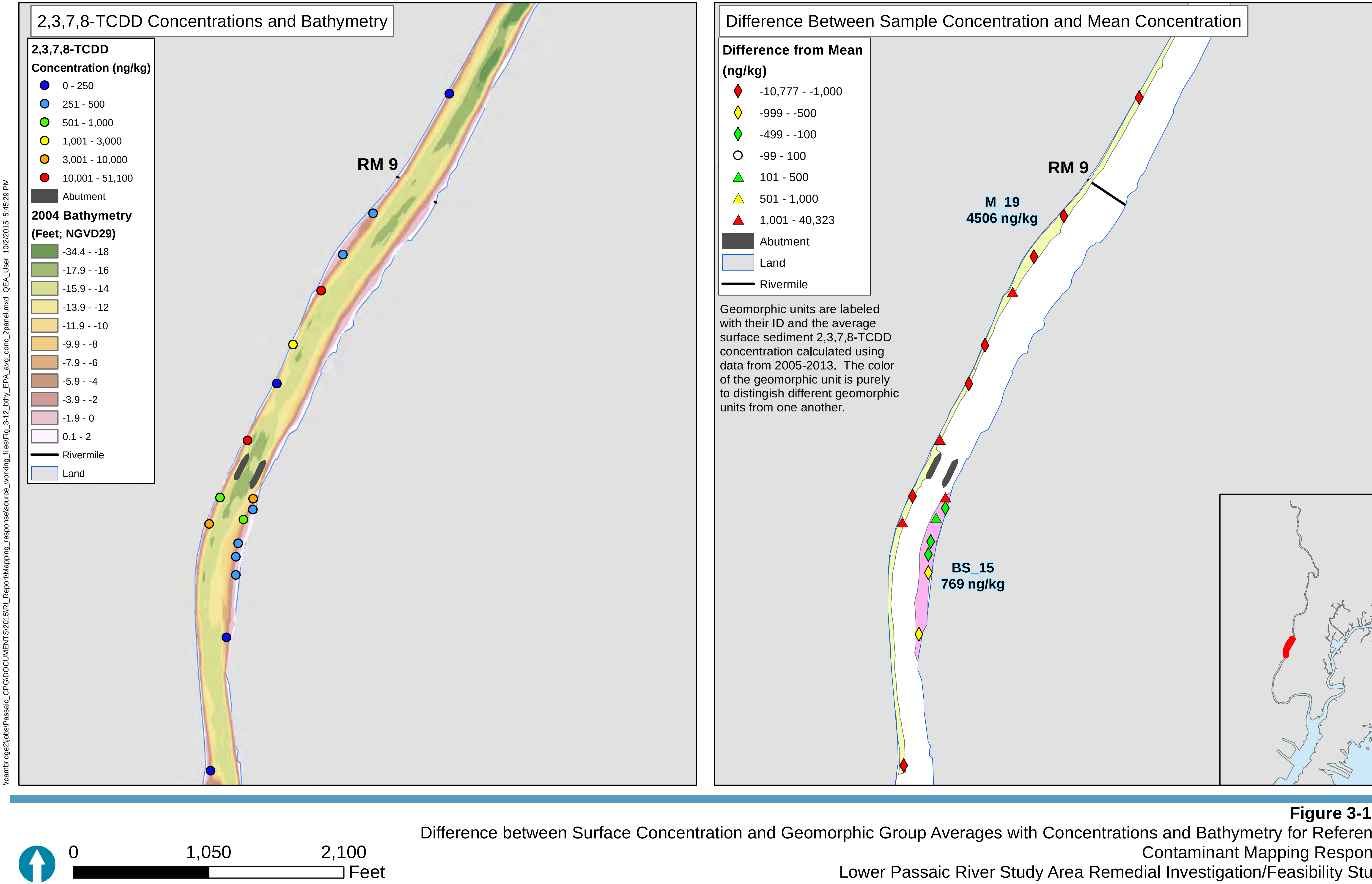





**Figure 3-12d**
Difference between Surface Concentration and Geomorphic Group Averages with Concentrations and Bathymetry for Reference
Contaminant Mapping Response
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

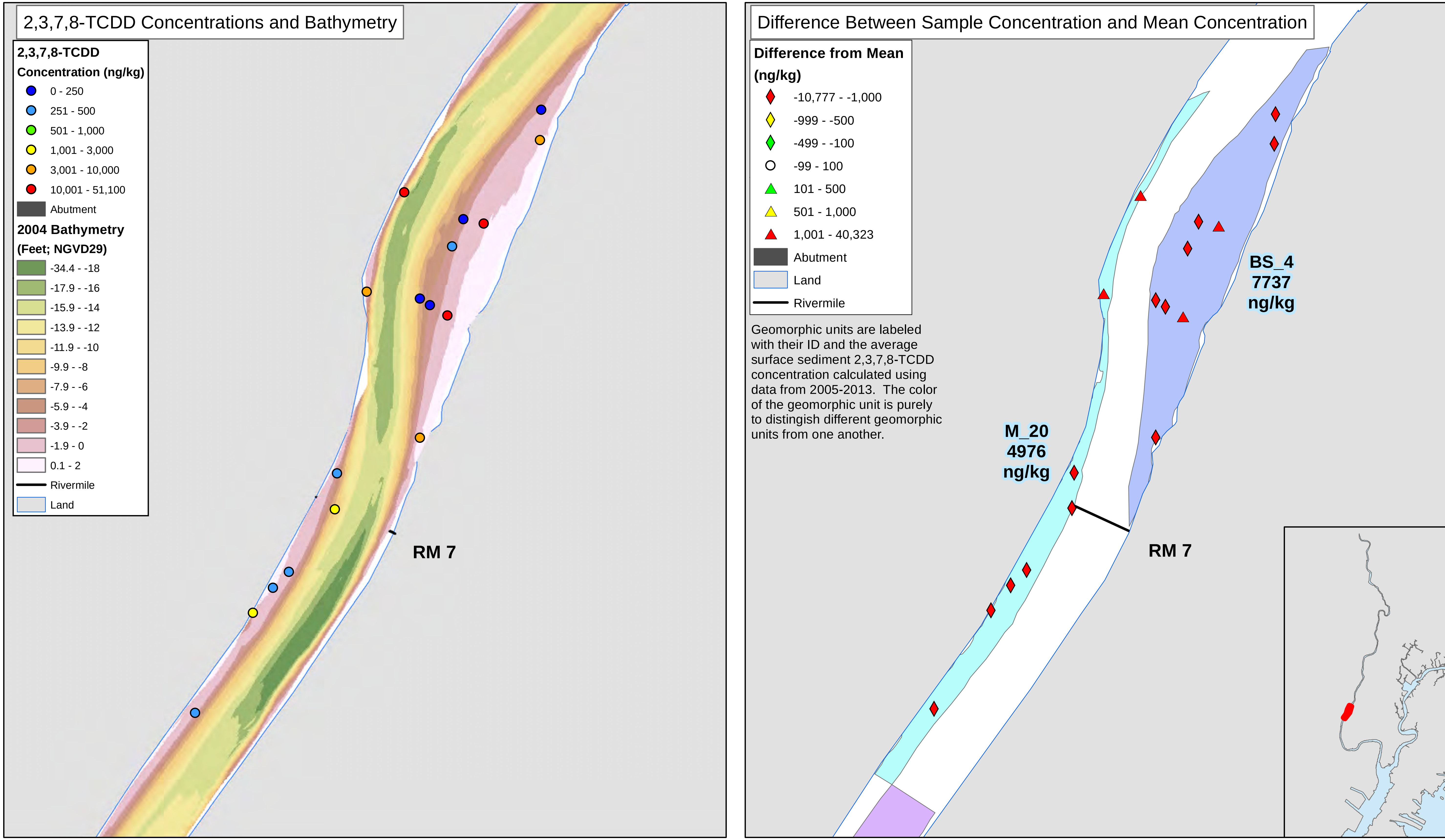



**Figure 3-12e**

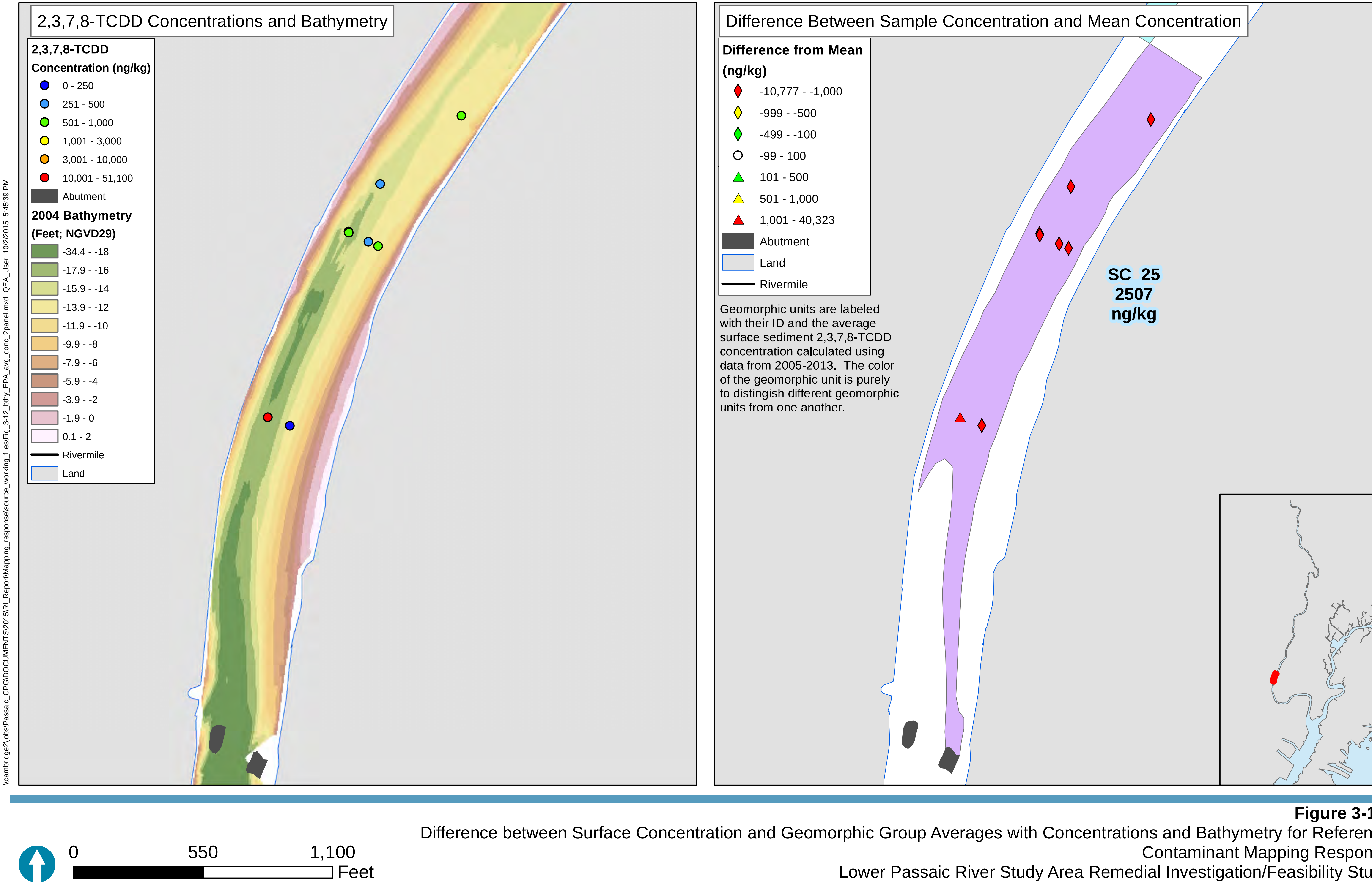
Difference between Surface Concentration and Geomorphic Group Averages with Concentrations and Bathymetry for Reference

Contaminant Mapping Response

Lower Passaic River Study Area Remedial Investigation/Feasibility Study

0 700 1,400

Feet



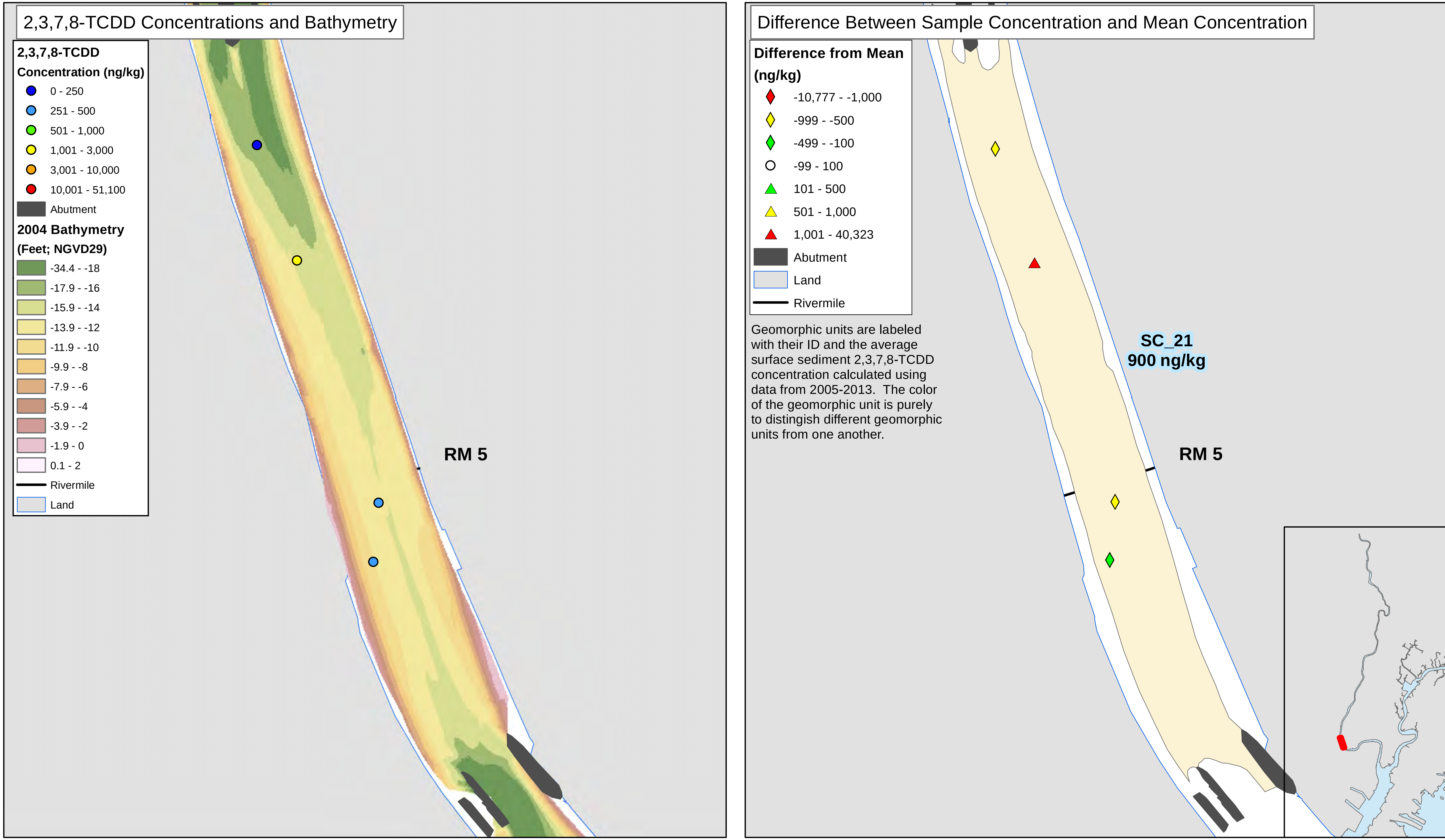

\\cambridge2\jobs\Passaic_CPG\DOCUMENTS\2015\RI_Report\Mapping_response\source_working_files\Fig_3-12_bthy_EPA_avg_conc_2panel.mxd QEA_User 10/2/2015 5:45:39 PM

**Figure 3-12f**

Difference between Surface Concentration and Geomorphic Group Averages with Concentrations and Bathymetry for Reference

Contaminant Mapping Response

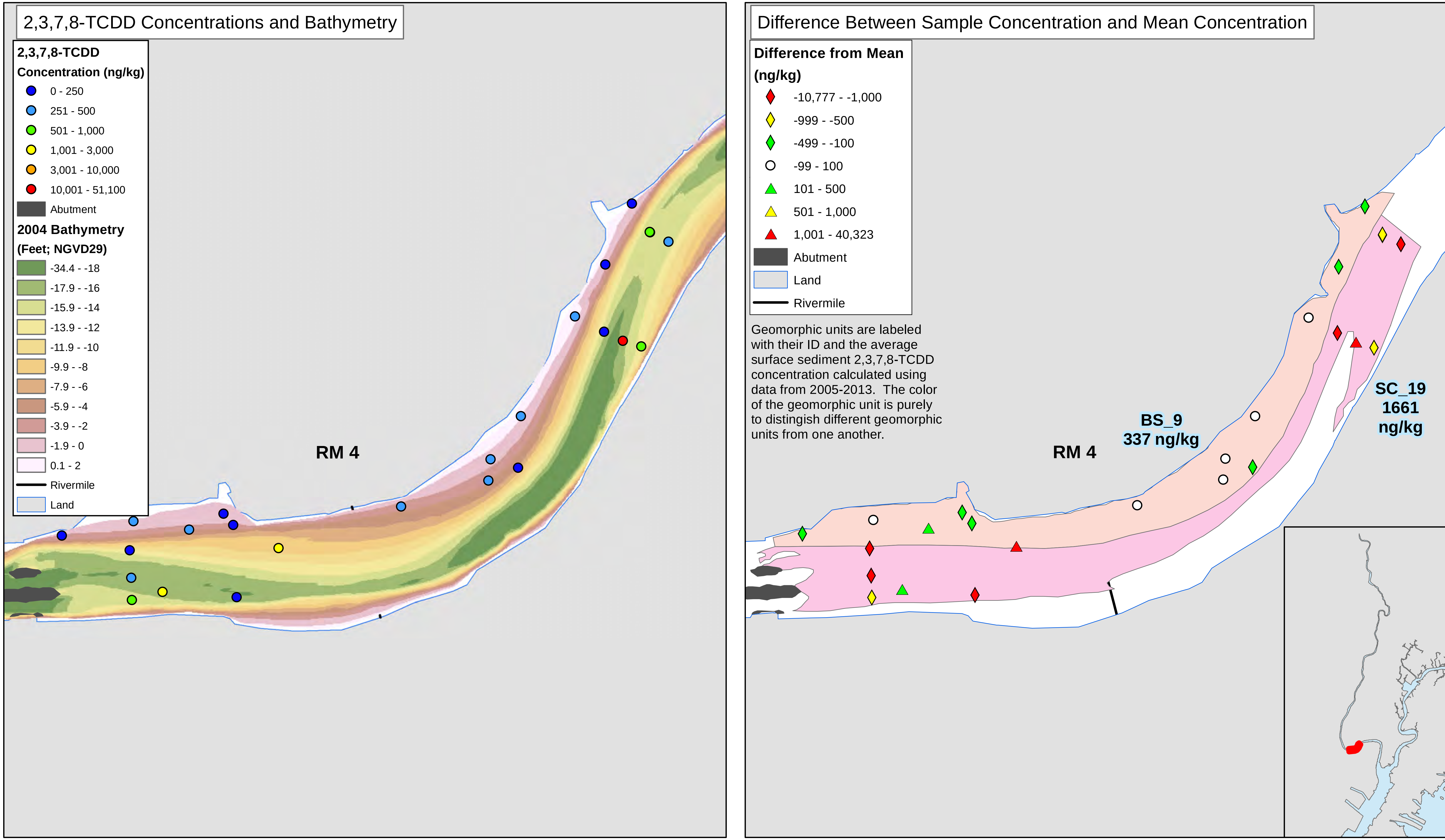
Lower Passaic River Study Area Remedial Investigation/Feasibility Study






0 600 1,200
Feet

**Figure 3-12g**
Difference between Surface Concentration and Geomorphic Group Averages with Concentrations and Bathymetry for Reference
Contaminant Mapping Response
Lower Passaic River Study Area Remedial Investigation/Feasibility Study



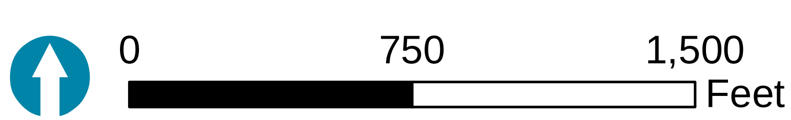
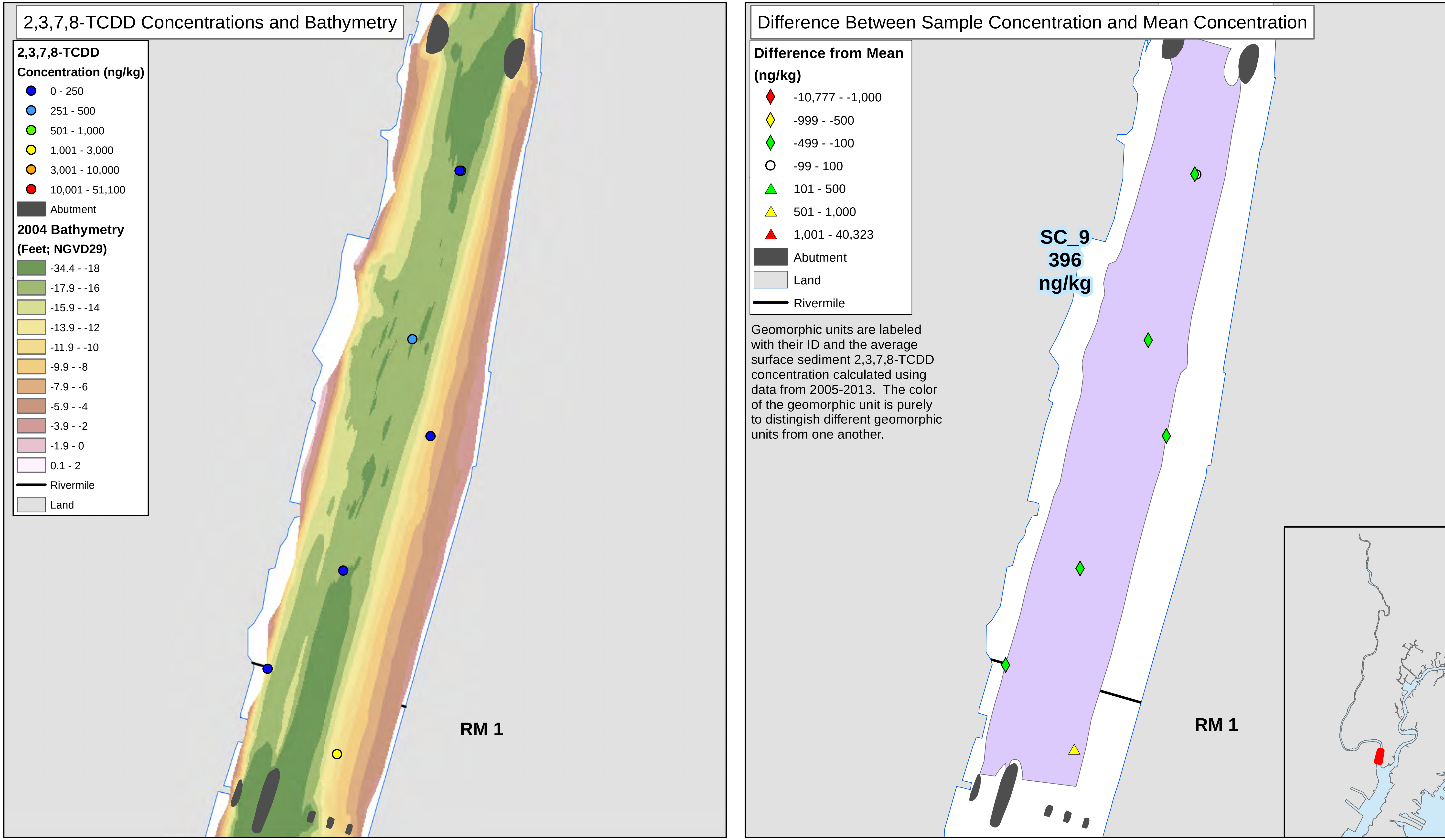




**Figure 3-12h**

Difference between Surface Concentration and Geomorphic Group Averages with Concentrations and Bathymetry for Reference

Contaminant Mapping Response

Lower Passaic River Study Area Remedial Investigation/Feasibility Study




\\cambridge2\jobs\Passaic_CPG\DOCUMENTS\2015\RI_Report\Mapping_response\source_working_files\Fig_3-12_bthy_EPA_avg_conc_2panel.mxd QEA_User 10/2/2015 5:45:54 PM

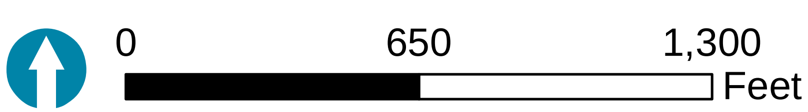



**Figure 3-12i**

Difference between Surface Concentration and Geomorphic Group Averages with Concentrations and Bathymetry for Reference

Contaminant Mapping Response

Lower Passaic River Study Area Remedial Investigation/Feasibility Study

# APPENDIX A
# PRESENTATION TO REGION 2 ON THE LOWER PASSAIC RIVER MAPPING APPROACH, MARCH 11, 2015

# LPR Contaminant Mapping Approach

Presentation to EPA

March 11, 2015

EPA Region 2 Office

# Outline

- Objectives of the mapping
- Predictability of sediment contaminant concentrations (patterns relate to bed evolution)
  - Focus on 2,3,7,8-TCDD, but most other contaminants show comparable patterns
- Partitioning the river to account for geomorphological influences on concentrations
- Approach to LPR contaminant mapping
  - Precedent for Using Thiessen Polygon Interpolation for RI/FS Work
  - Apply Thiessen Polygon interpolation within partitioned river

# Objectives of the Mapping

- Approximately delineate the regions of high concentration to support the goal of characterizing nature and extent of contamination
- Provide an *approximate* (i.e., "FS Level") representation of sediment contaminant concentrations throughout the LPR
  - Needed to examine remedial alternatives
  - Needed to model contaminant fate and transport and bioaccumulation
- Objectives recognize that more refined mapping will be undertaken as part of remedy design

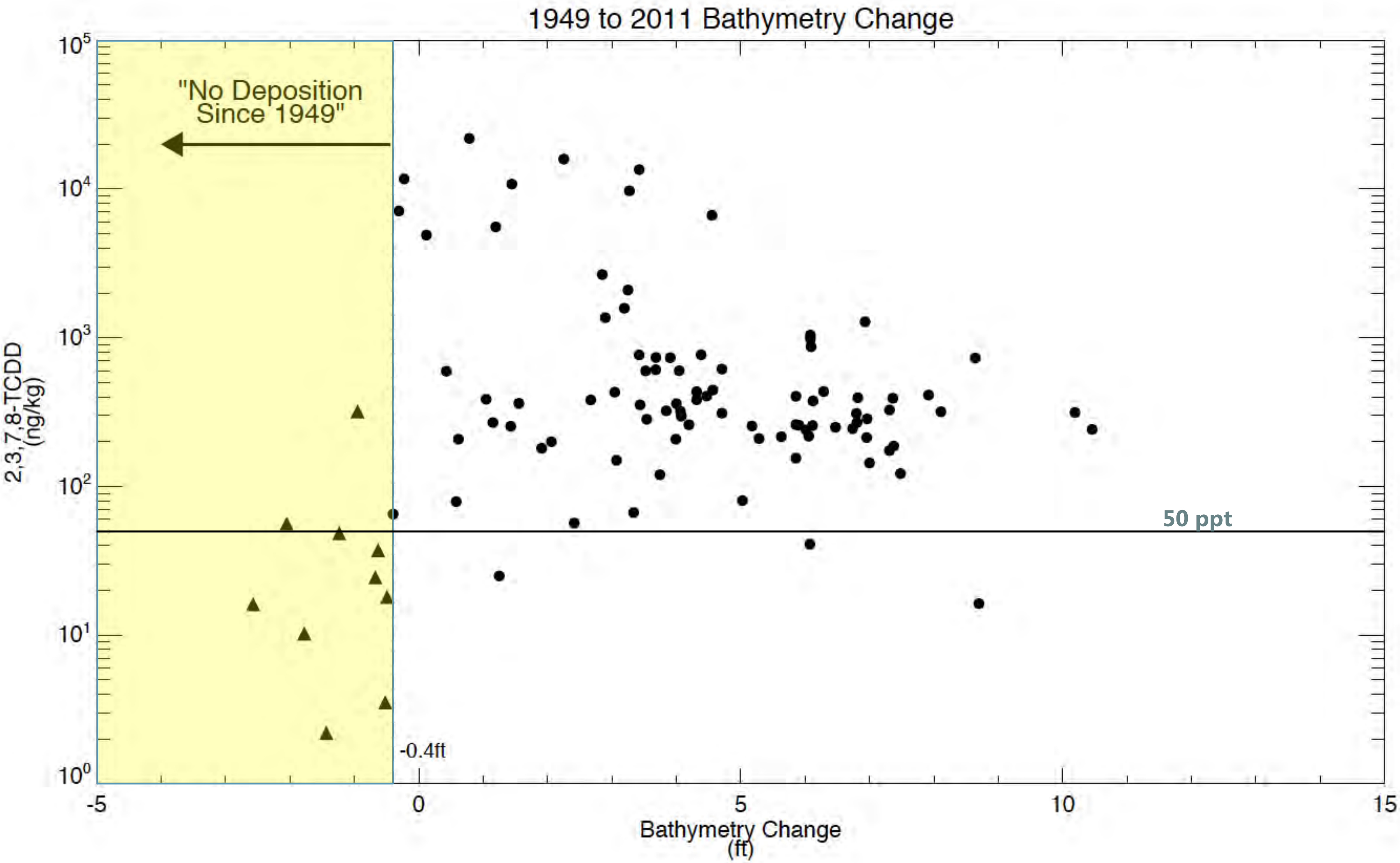
# Data Used in the Mapping

| Study Name | Years | Centroid | Data Counts | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | TCDD | Total PCBs | Mercury | HMW PAH | LMW PAH | Total DDx |
| Honeywell International Sampling Programs | 2005, 2006 | no | 2 | 2 | 2 | 2 | 2 | 0 |
| USEPA/MPI – High-Resolution Sediment Coring Program | 2005, 2006, 2008 | no | 1 | 1 | 0 | 1 | 1 | 0 |
| USEPA/MPI – EMBM | 2007, 2008 | no | 18 | 18 | 18 | 18 | 18 | 9 |
| Low-Resolution Coring Program | 2008 | yes | 90 | 91 | 91 | 91 | 91 | 90 |
| USEPA/MPI – Sediment Sampling Program | 2008 | no | 10 | 10 | 17 | 10 | 10 | 10 |
| Benthic Program Surface Sediment Sampling (2009) | 2009 | no | 110 | 110 | 110 | 0 | 110 | 110 |
| Benthic Program Surface Sediment Sampling (2010) | 2010 | no | 21 | 21 | 21 | 0 | 21 | 21 |
| River Mile 10.9 Characterization | 2011 | yes | 54 | 54 | 54 | 54 | 54 | 54 |
| Low-resolution Coring Program Supplemental Sampling Program | 2012 | yes | 85 | 85 | 85 | 85 | 85 | 85 |
| Tierra – Focused Sediment Investigation (RM 10.9) | 2012 | no | 6 | 0 | 0 | 0 | 0 | 0 |
| River Mile 10.9 Addendum A | 2012 | yes | 15 | 15 | 15 | 15 | 15 | 15 |
| Low-resolution Coring Program Supplemental Sampling Program 2 | 2013 | yes | 75 | 74 | 74 | 72 | 72 | 74 |

Most of the samples collected between 2008 and 2013

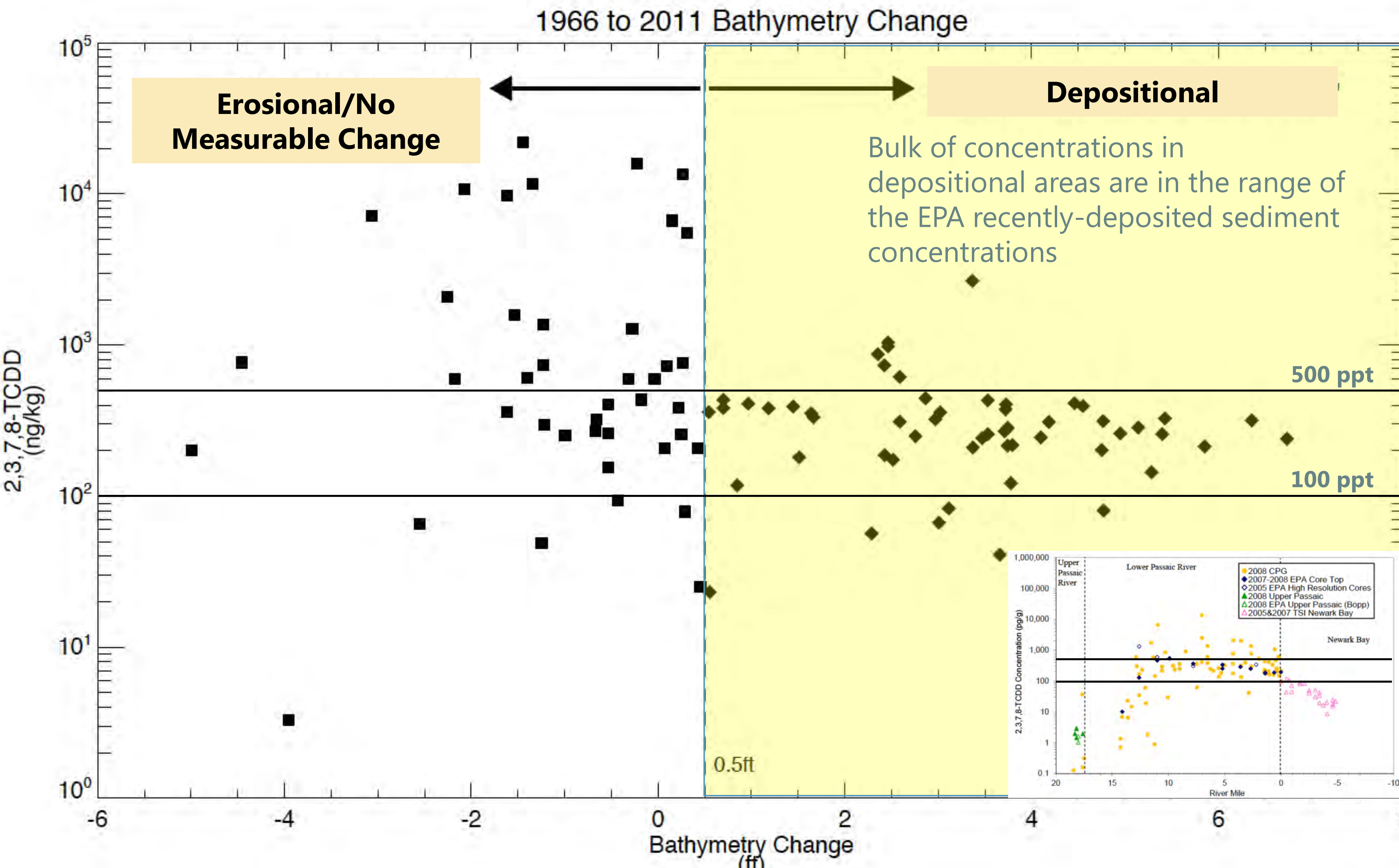
# Channel Concentrations Relate to Erosion/Deposition History

# As Expected, Channel Locations Lacking Post-1949 Sediments Have Low Concentrations




Subject to bathymetry mapping uncertainty

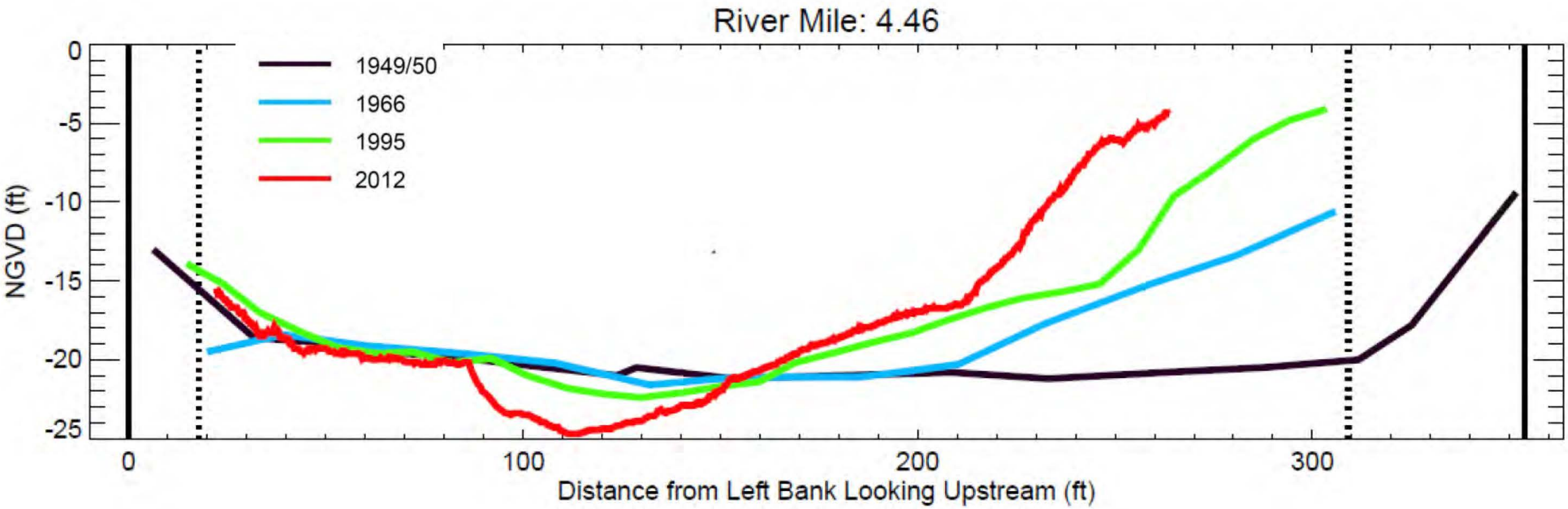
# Highest Concentrations in Channel at Locations Having Post-'49 Sediments, But Erosion/No Change Since '66

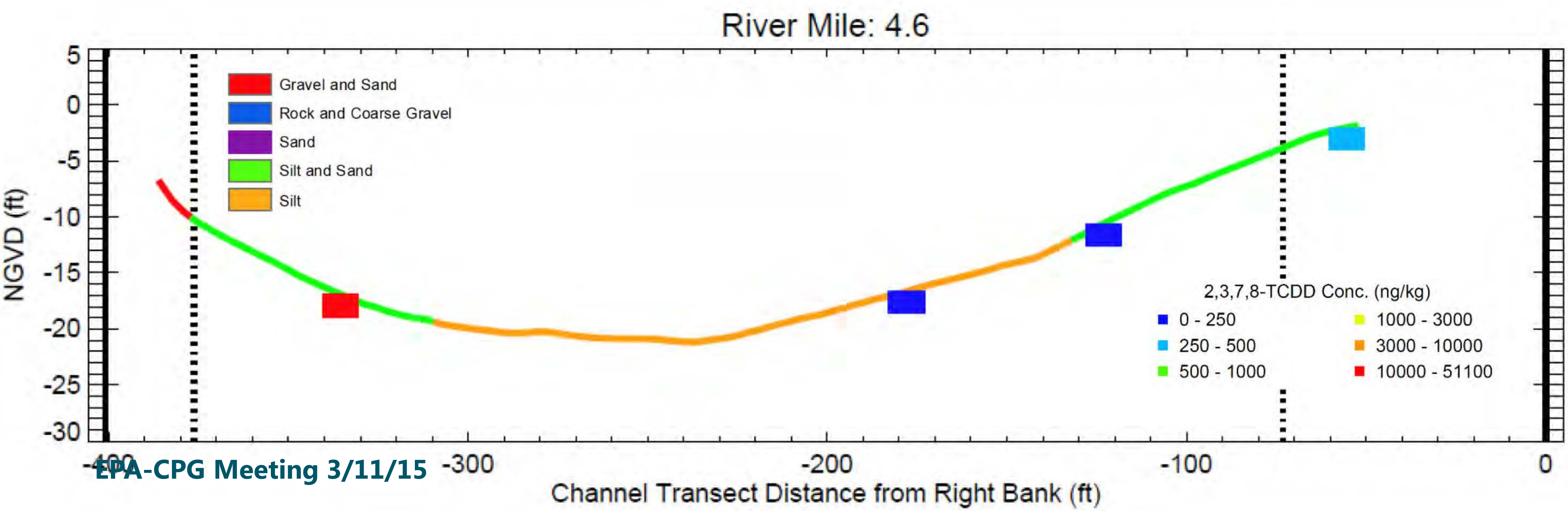



Subject to bathymetry mapping uncertainty

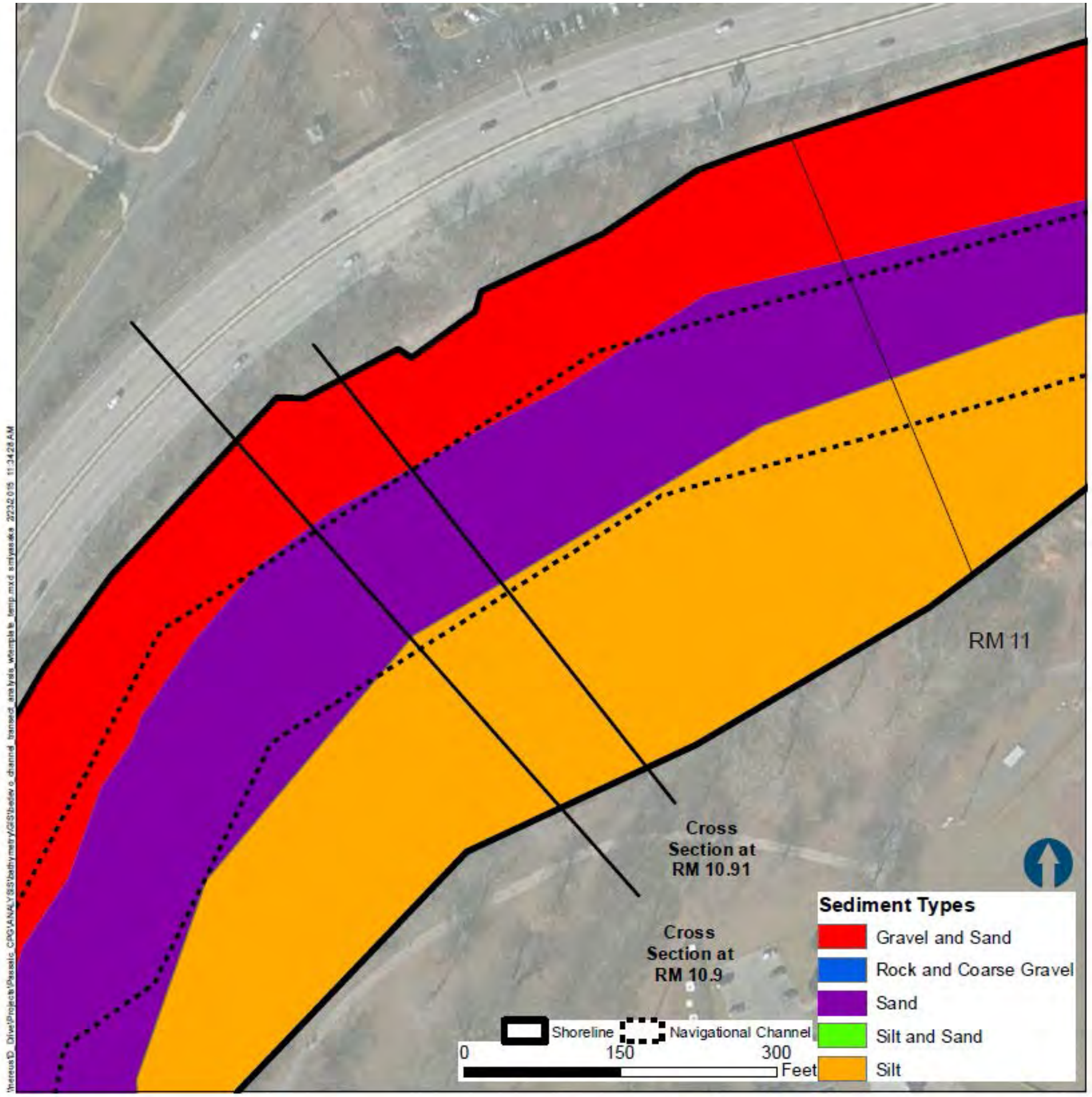
# Transects to Examine Bed Evolution and Contaminant Concentrations

# Example of Relationship Between Surface Sediment Concentration and Bed Evolution

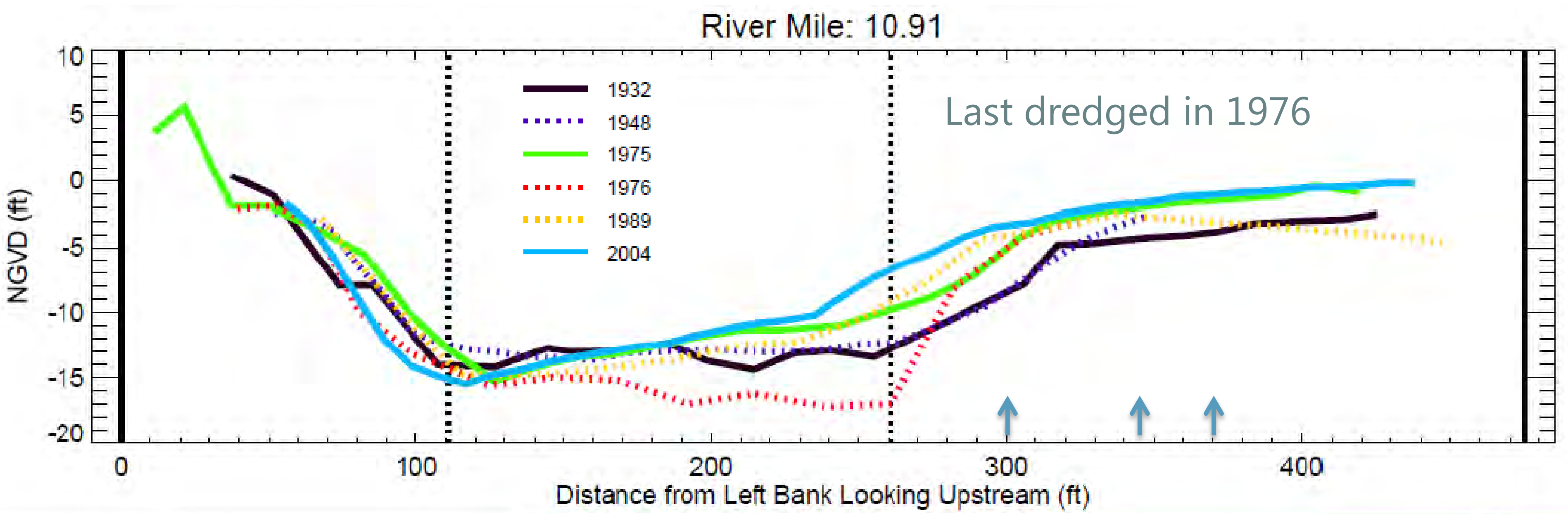


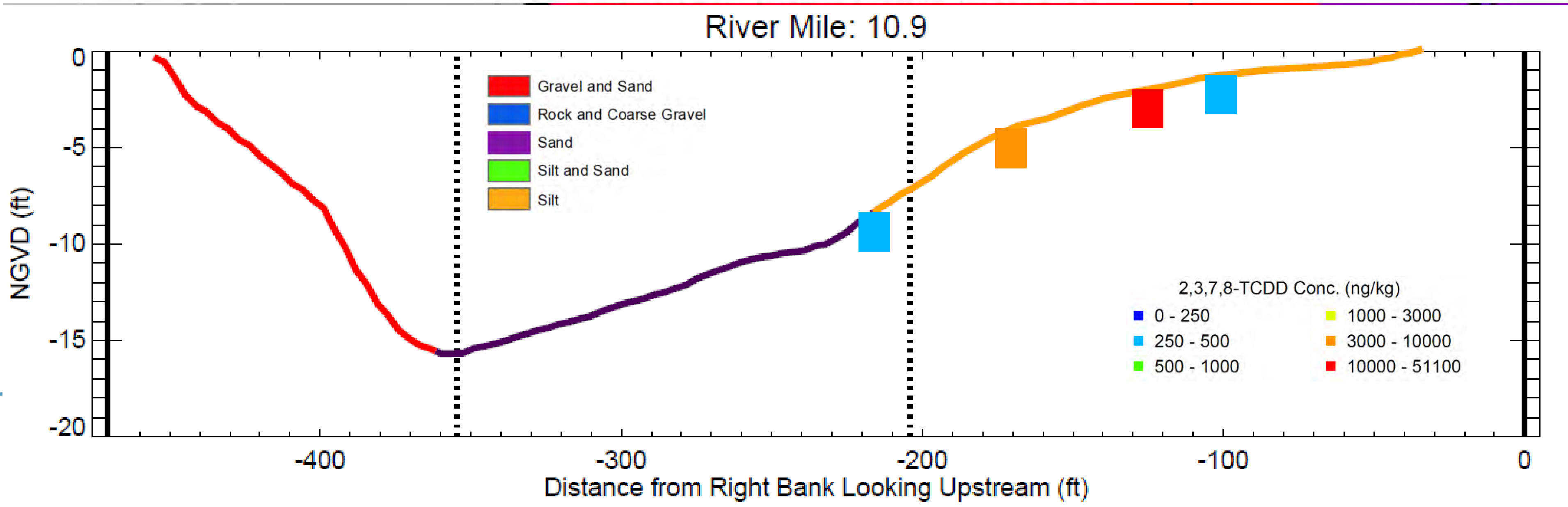



# Transects to Examine Bed Evolution and Contaminant Concentrations

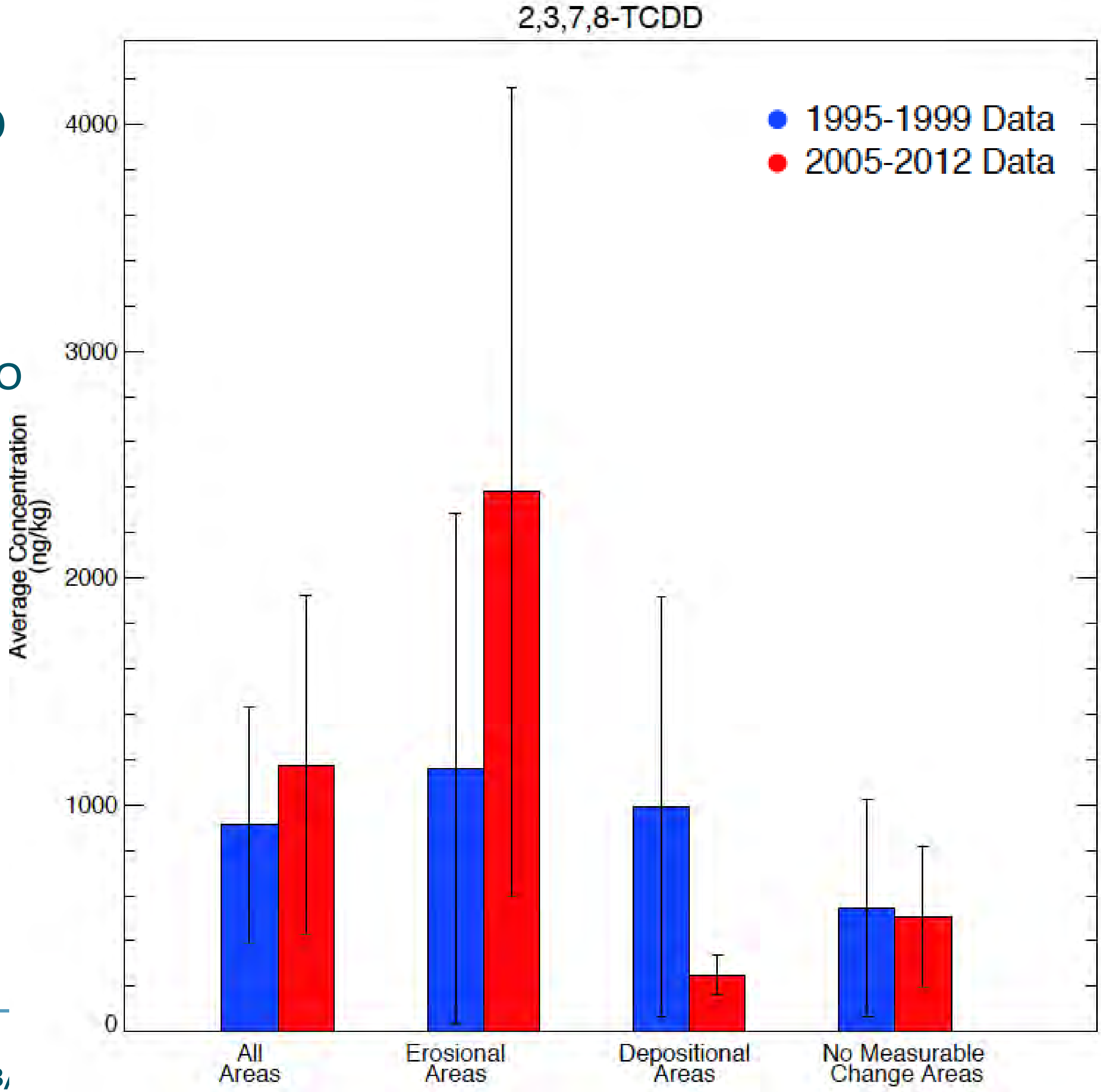


# Example of Relationship Between Surface Sediment Concentration and Bed Evolution



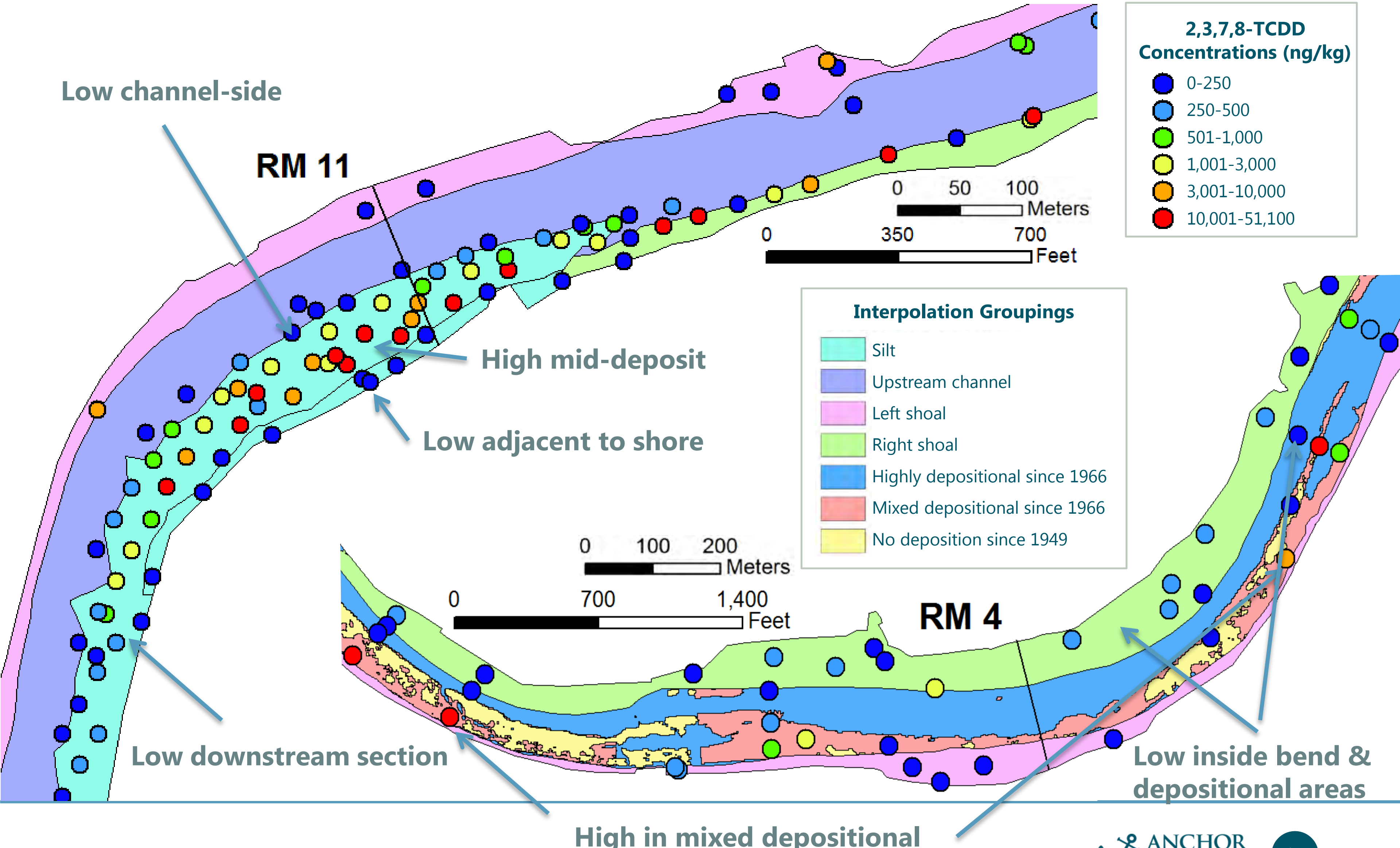



# Surface 2,3,7,8-TCDD Changes Relate to Recent Erosion/Deposition



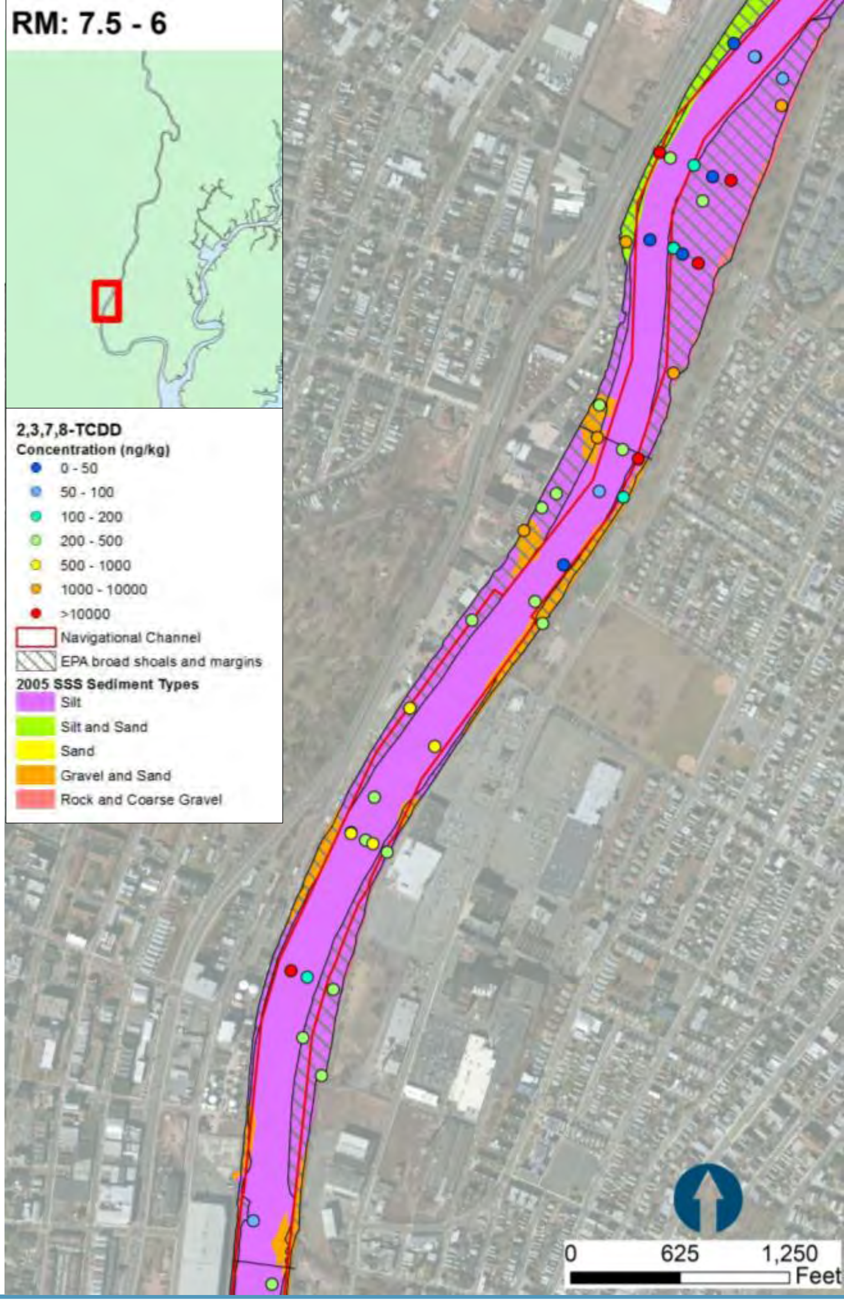
# Local Patterns Exist

# Patterns Exist at the Sub-Deposit Scale



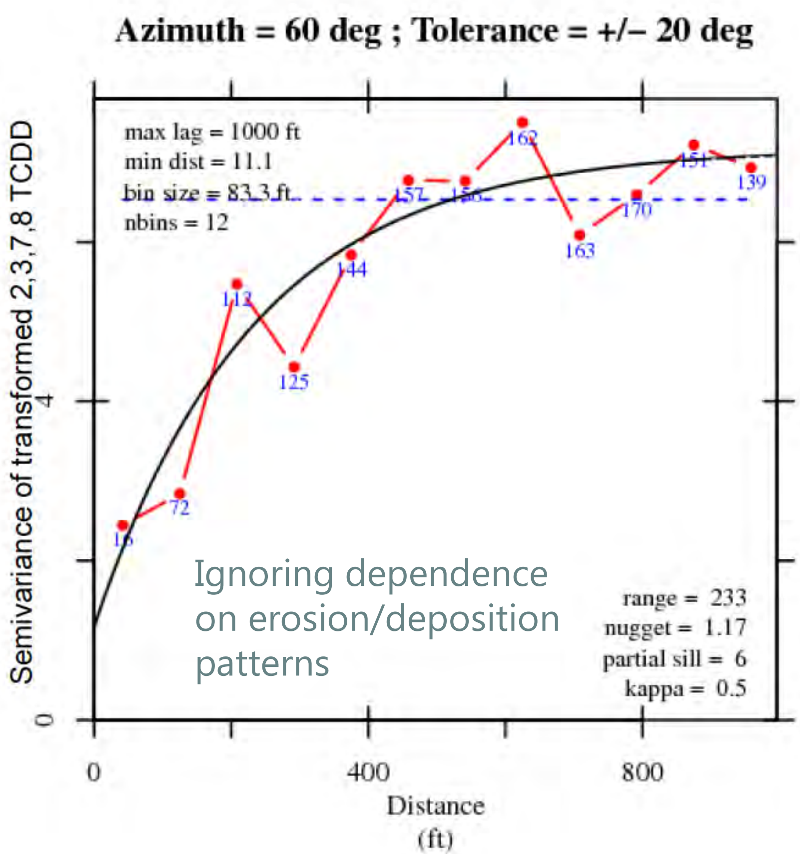
# Along-River Correlation Within Deposits

- Cross-river gradients reflecting geomorphology



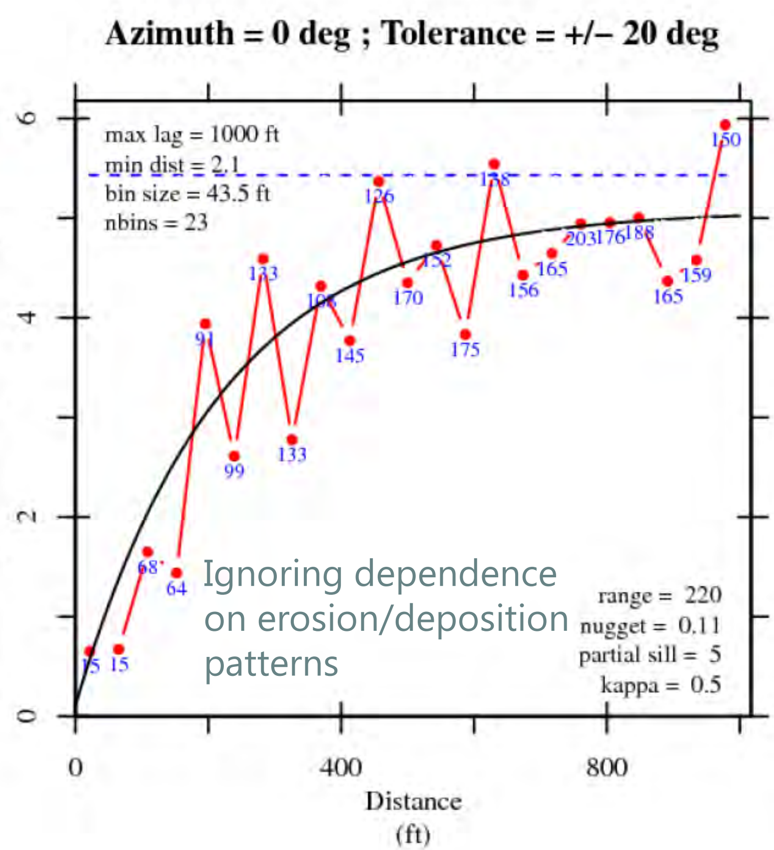
# Variogram Shows Along-River Concentration Correlation on the Scale of Several Hundred Feet

## RM 10.9 Deposit



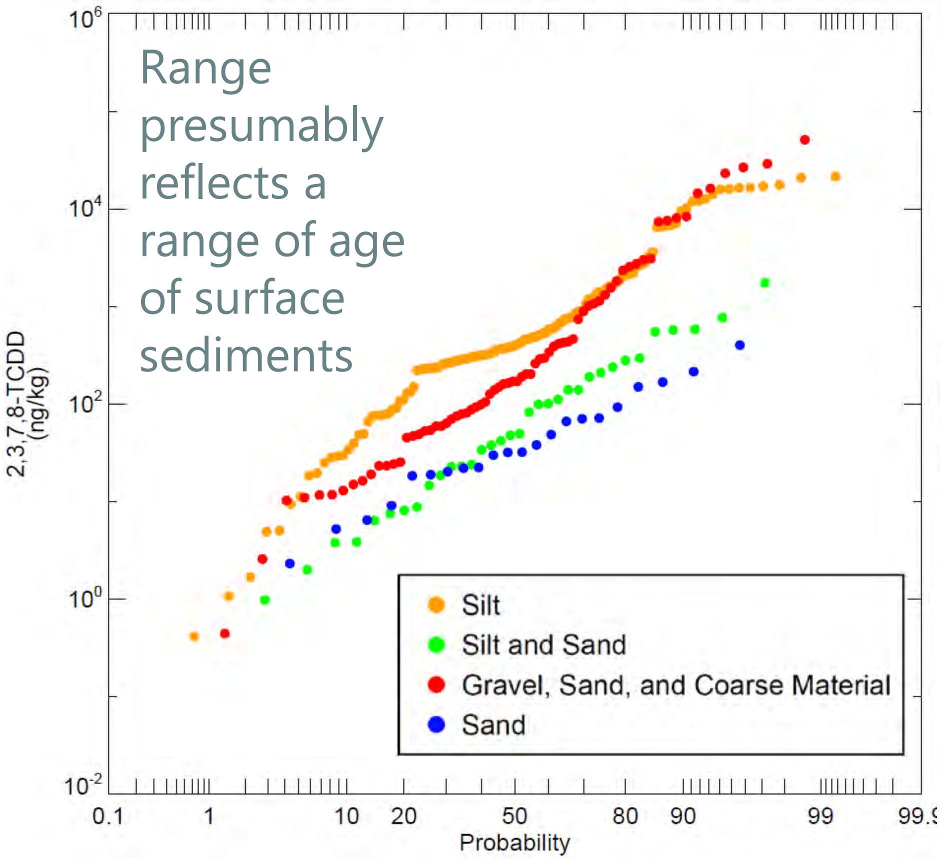

Ignoring dependence on erosion/deposition patterns

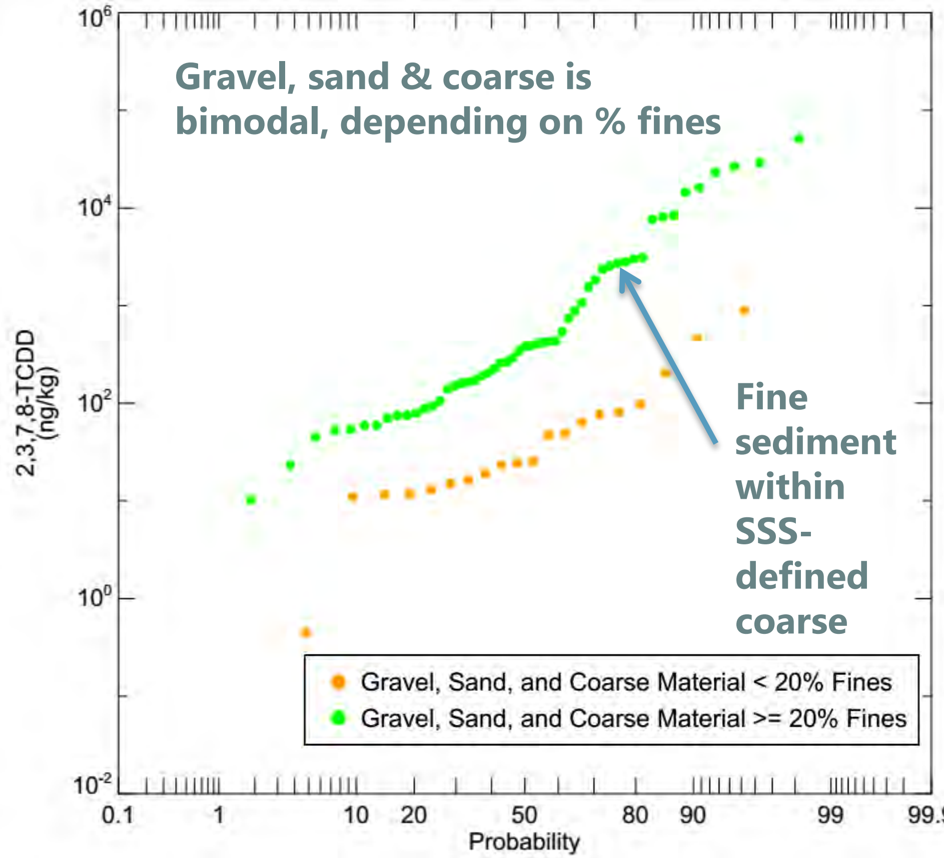
## Straightened River, All Data




Ignoring dependence on erosion/deposition patterns

# RM 7.8-14 Concentrations Vary Among the Sediment Types

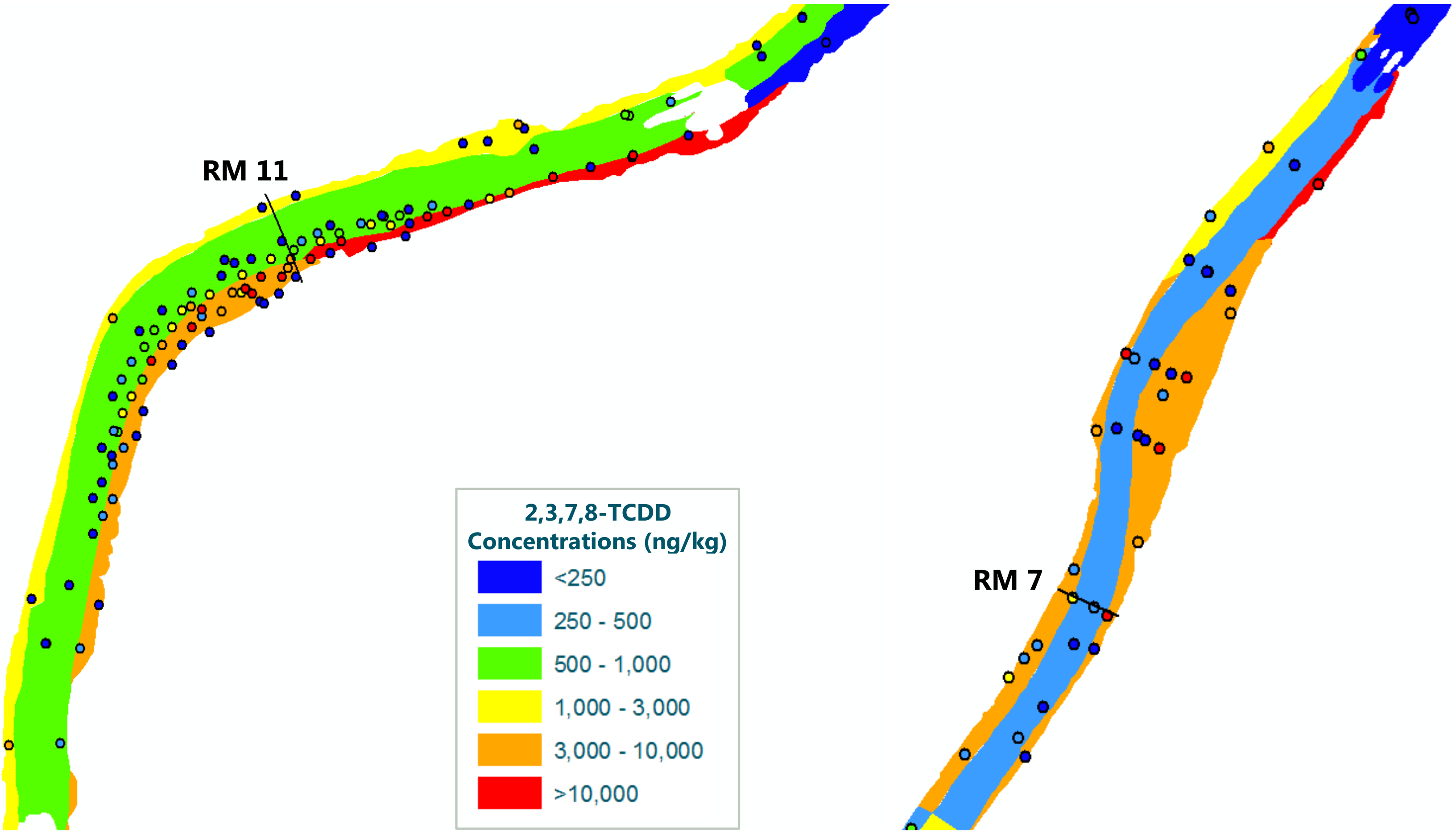


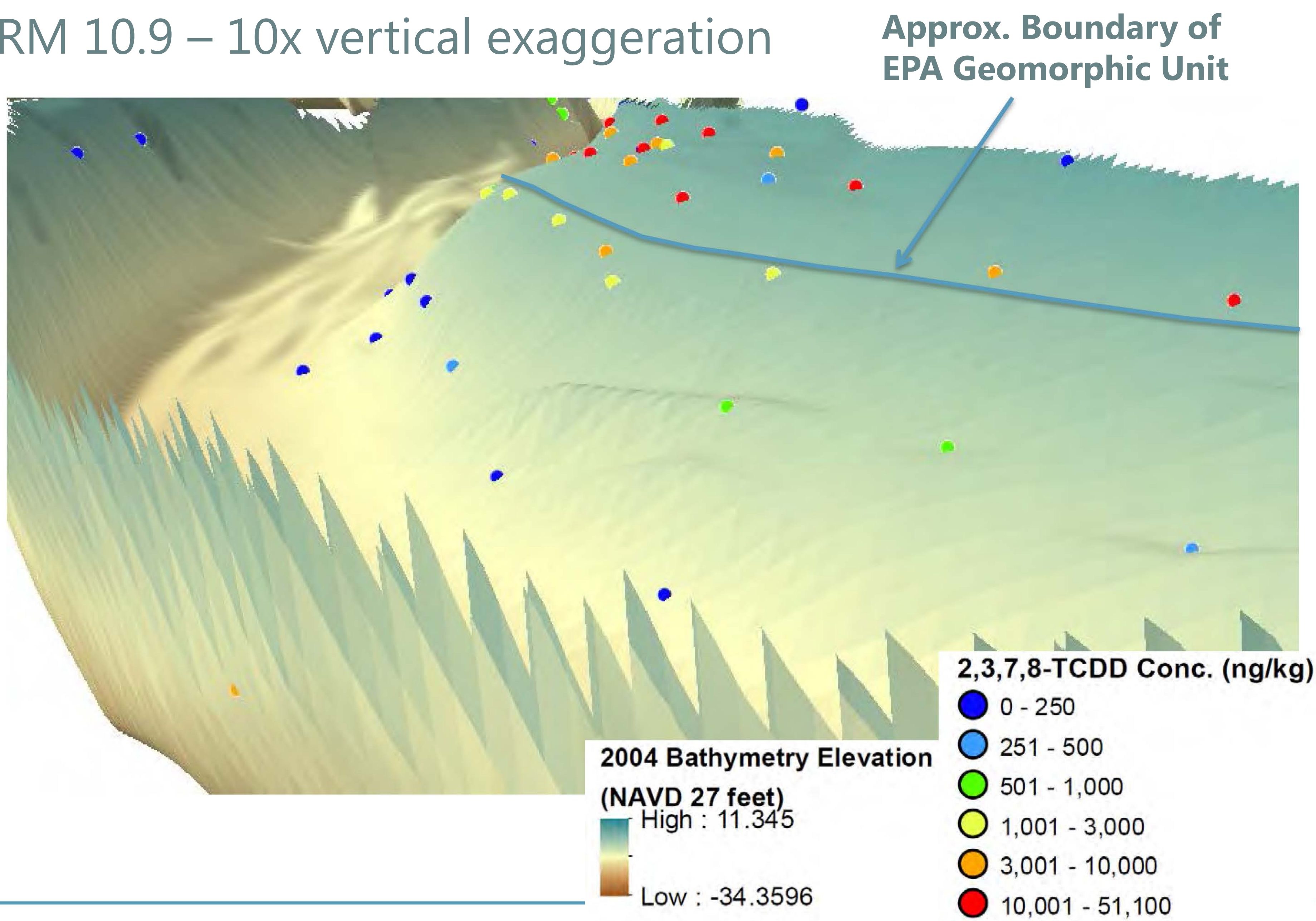

*Note: The 'Gravel, Sand and Coarse Material' category combines both 'Gravel and Sand' and 'Rock and Coarse Gravel' 2005 Side Scan Sonar classifications.*

# Broad-Scale Averaging (even within geomorphic units) Does Not Take Account of the Evident Patterns

# Disadvantage of Averaging is Seen When Comparing Averages to the Data

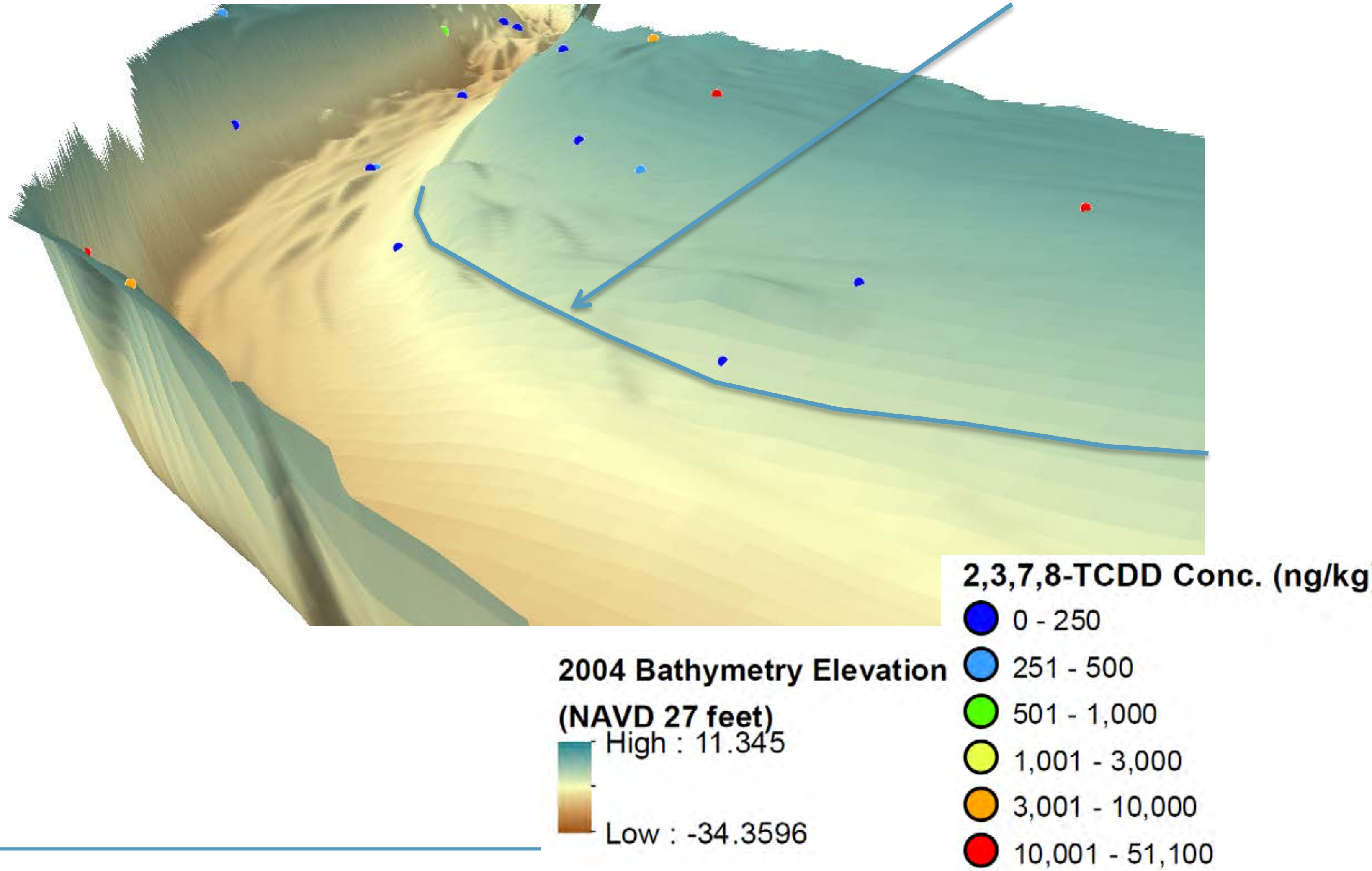


# RM 10.9 – 10x vertical exaggeration



# RM 7.5 – 10x vertical exaggeration

**Approx. Boundary of EPA Geomorphic Unit**



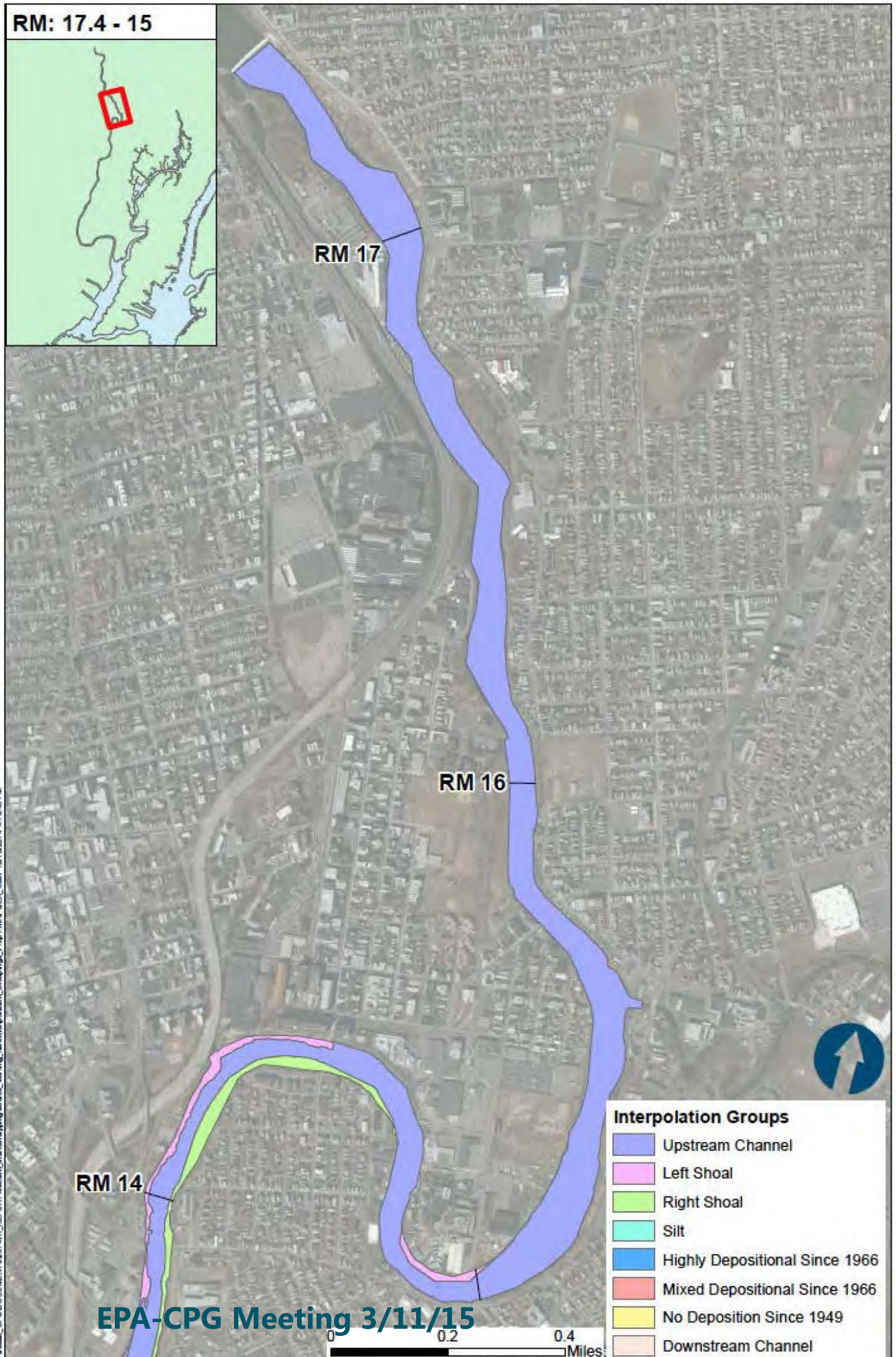
# River Stratified to Account for the Concentration Patterns

# Information Exists to Appropriately Partition the River

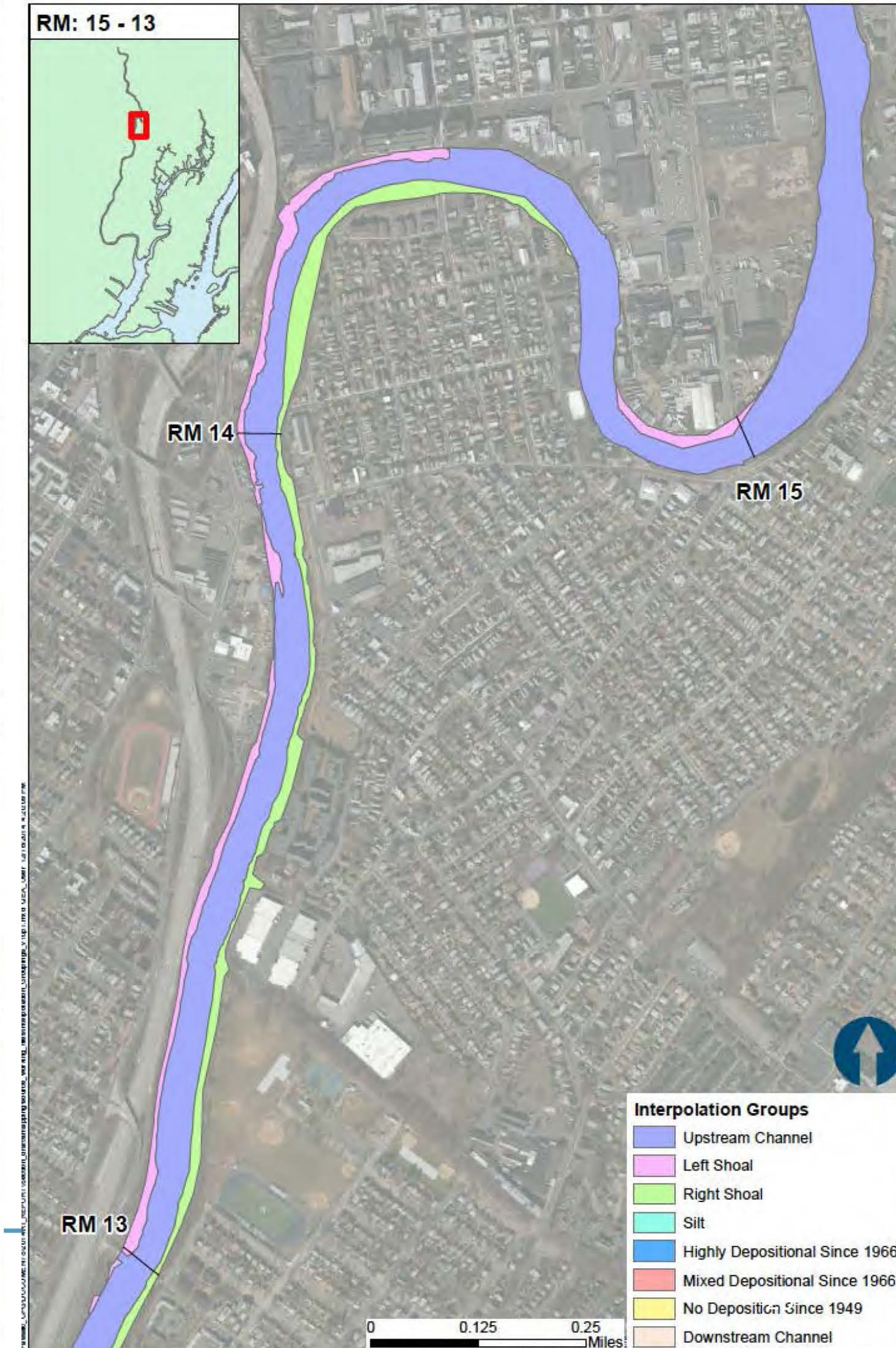
- Bathymetry measurements allow separation of shoals and channel
- Side-scan sonar and probing map sediment type
- Bathymetric differencing between surveys provides means to approximately identify net erosion/deposition patterns

# Acres for the Various Partitions of the River

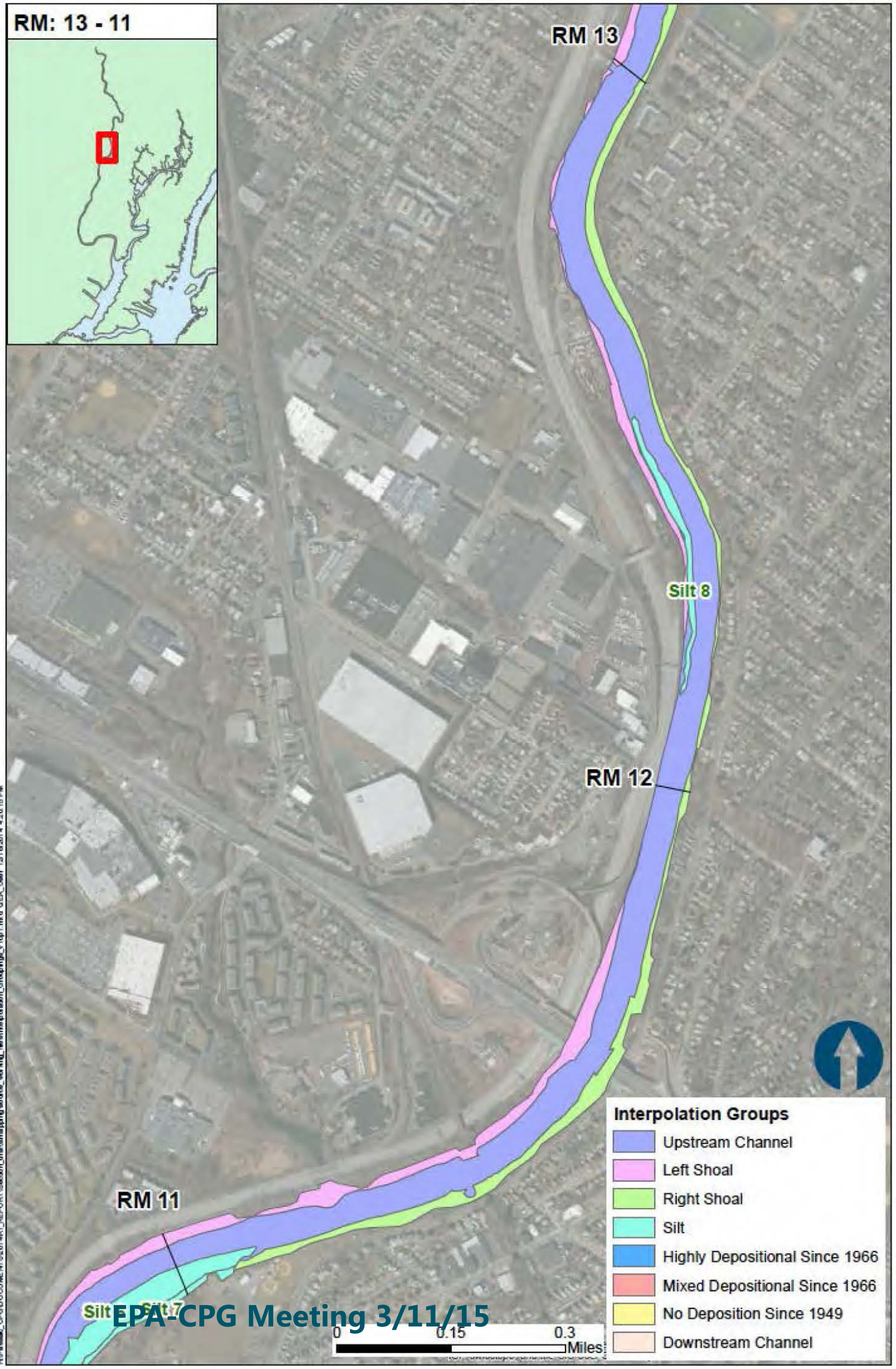
| | RM 0 – RM 8 | RM 8 – RM 14 | RM 14 – RM 17.6 |
|---|---|---|---|
| Shoal | 377 | 57 | 10 |
| Non-dep channel | 19 | | |
| Mixed dep channel | 50 | | |
| High dep channel | 112 | | |
| Silt deposits | 3 | 40 | |
| Channel | | 119 | 106 |
| RM10.9 Silt Deposit | | 13 | |
| Downstream Channel | 110 | | |



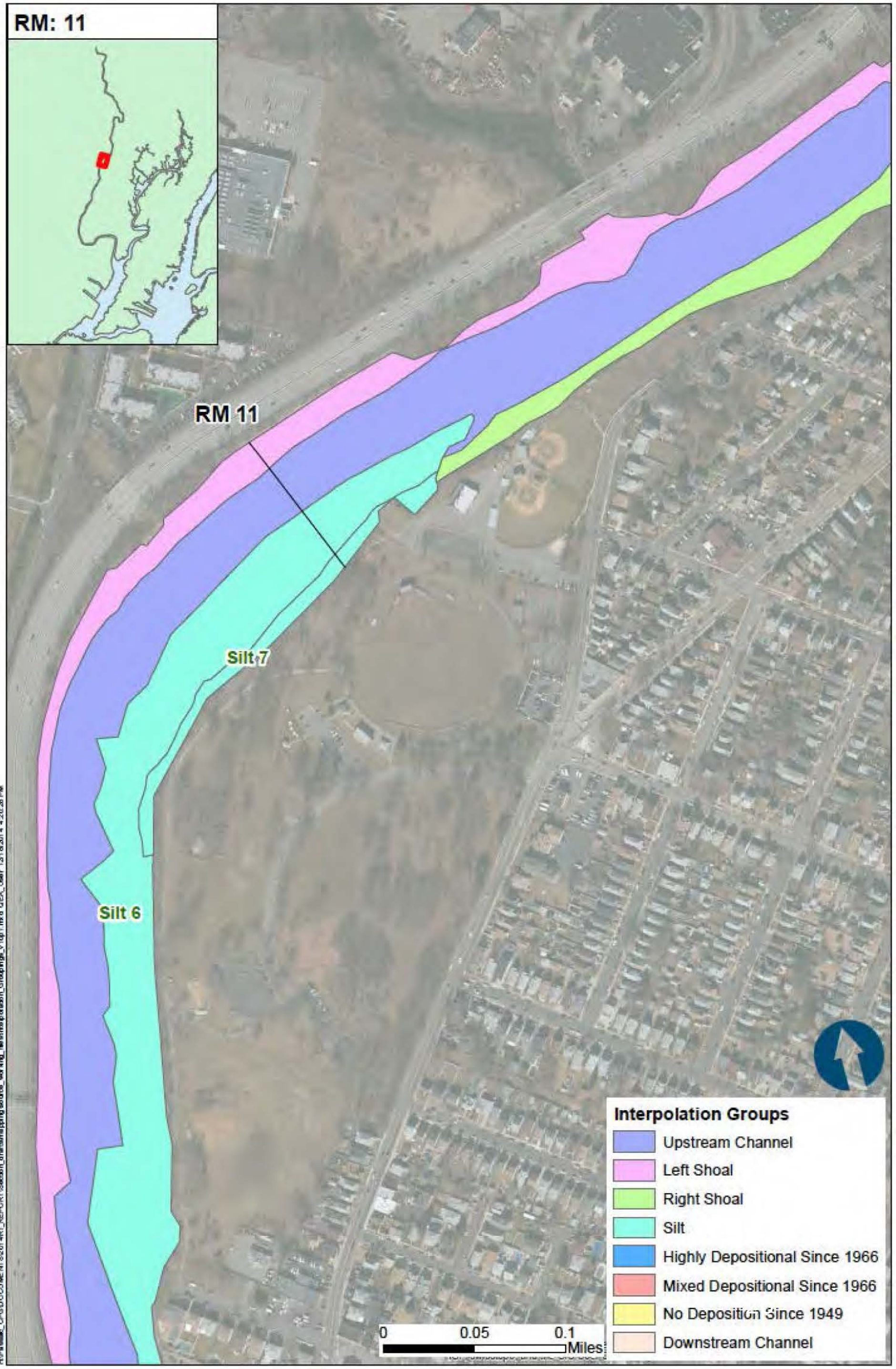
RM: 17.4 - 15
RM 17
RM 16
RM 14
Interpolation Groups
Upstream Channel
Left Shoal
Right Shoal
Silt
Highly Depositional Since 1966
Mixed Depositional Since 1966
No Deposition Since 1949
Downstream Channel
0
0.2
0.4
Miles

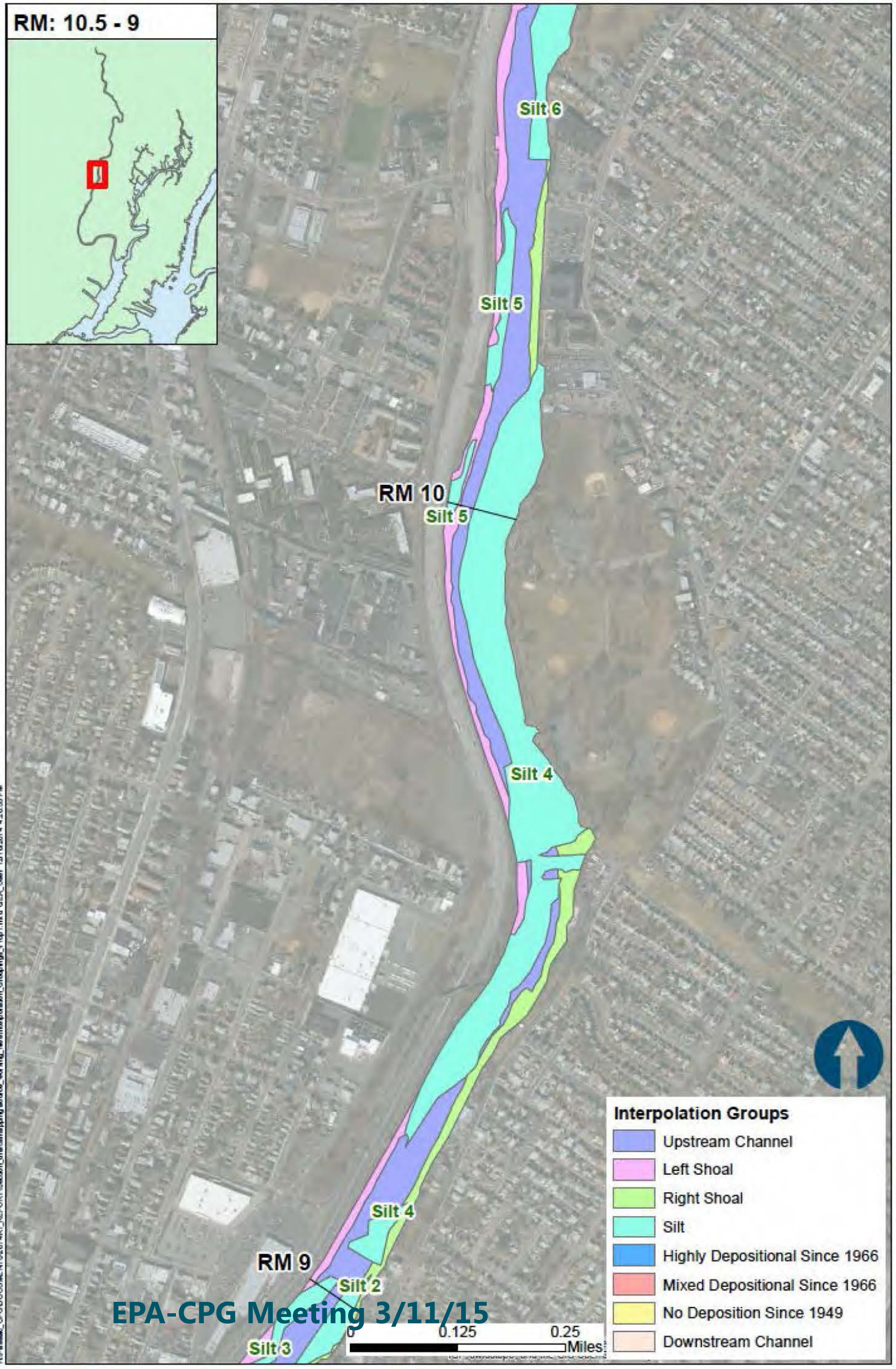
RM: 15 - 13
RM 15
RM 14
RM 13
Interpolation Groups
Upstream Channel
Left Shoal
Right Shoal
Silt
Highly Depositional Since 1966
Mixed Depositional Since 1966
No Deposition Since 1949
Downstream Channel
0
0.125
0.25
Miles

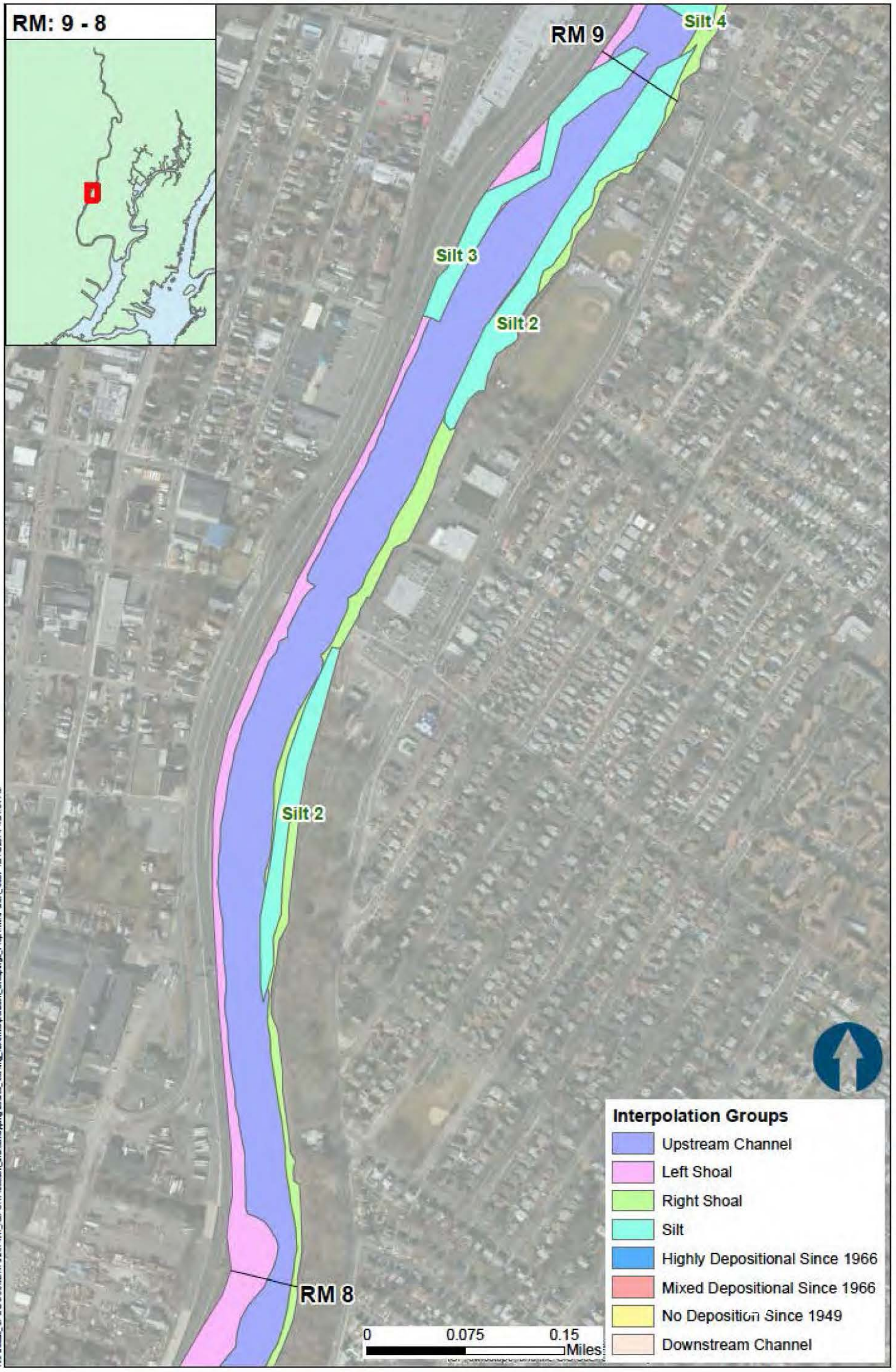


RM: 13 - 11
RM 13
Silt 8
RM 12
RM 11
Silt 7
Interpolation Groups
Upstream Channel
Left Shoal
Right Shoal
Silt
Highly Depositional Since 1966
Mixed Depositional Since 1966
No Deposition Since 1949
Downstream Channel
0 0.15 0.3 Miles

RM: 11
RM 11
Silt 7
Silt 6
Interpolation Groups
Upstream Channel
Left Shoal
Right Shoal
Silt
Highly Depositional Since 1966
Mixed Depositional Since 1966
No Deposition Since 1949
Downstream Channel
0 0.05 0.1 Miles

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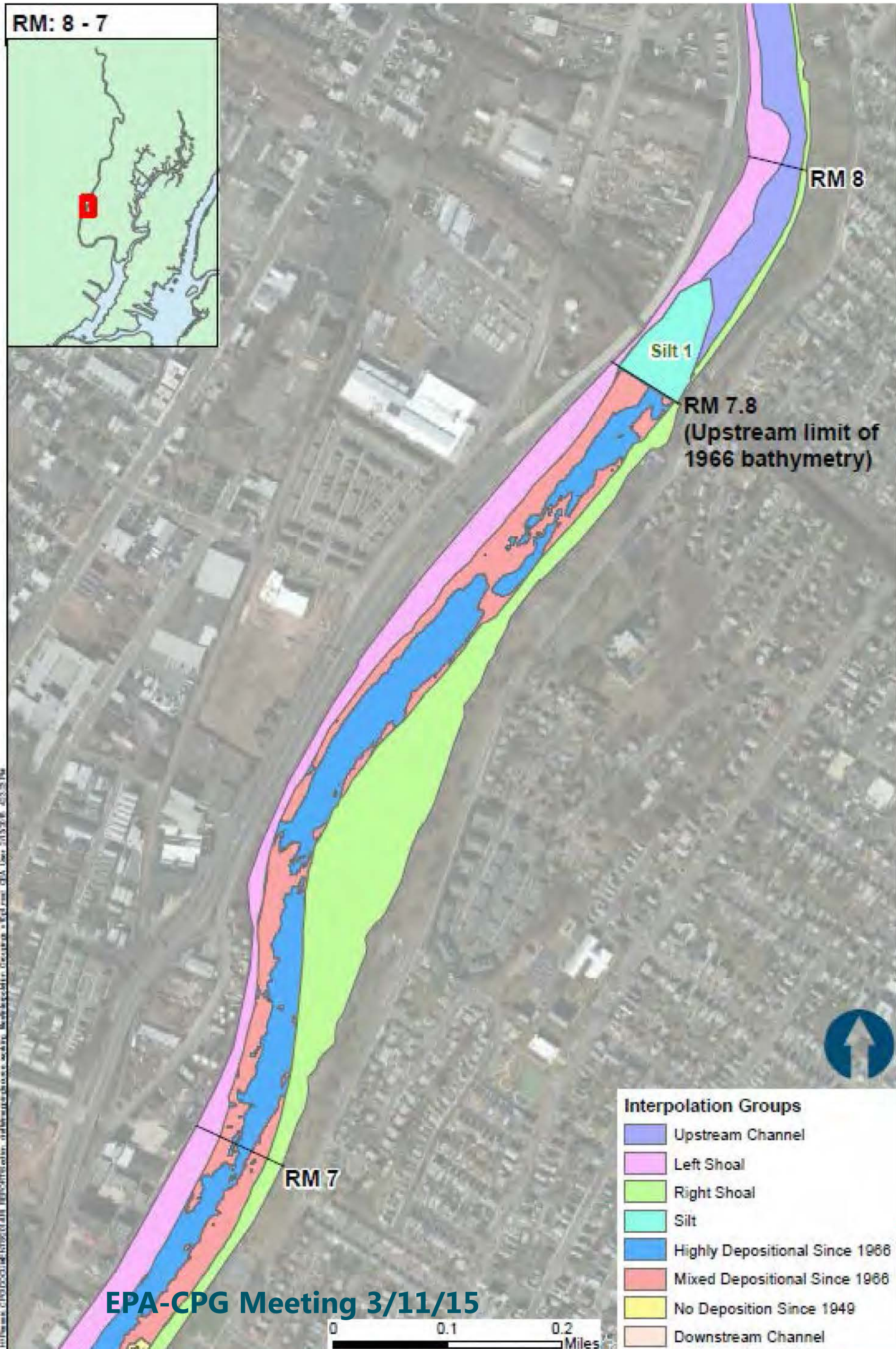
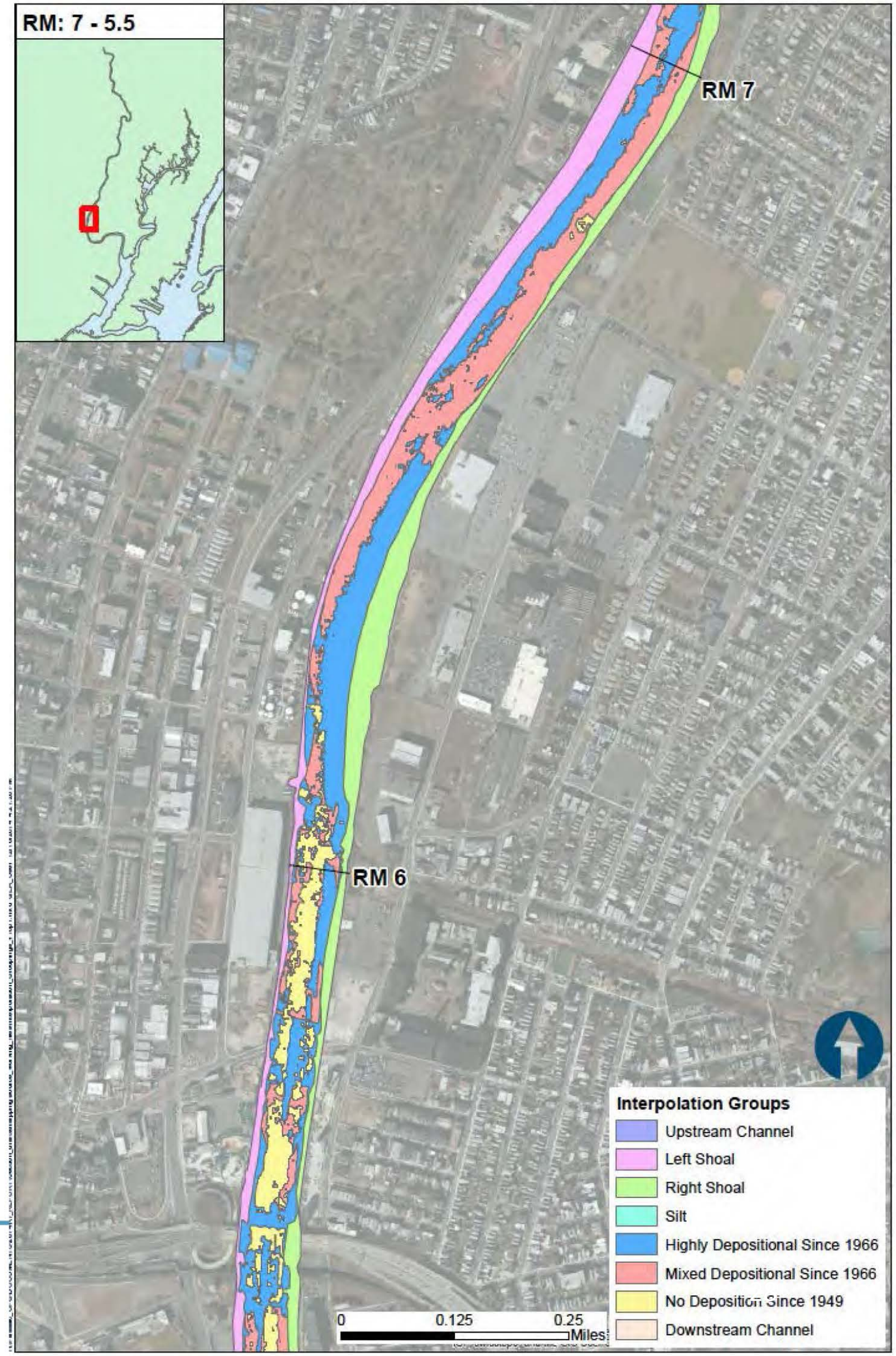
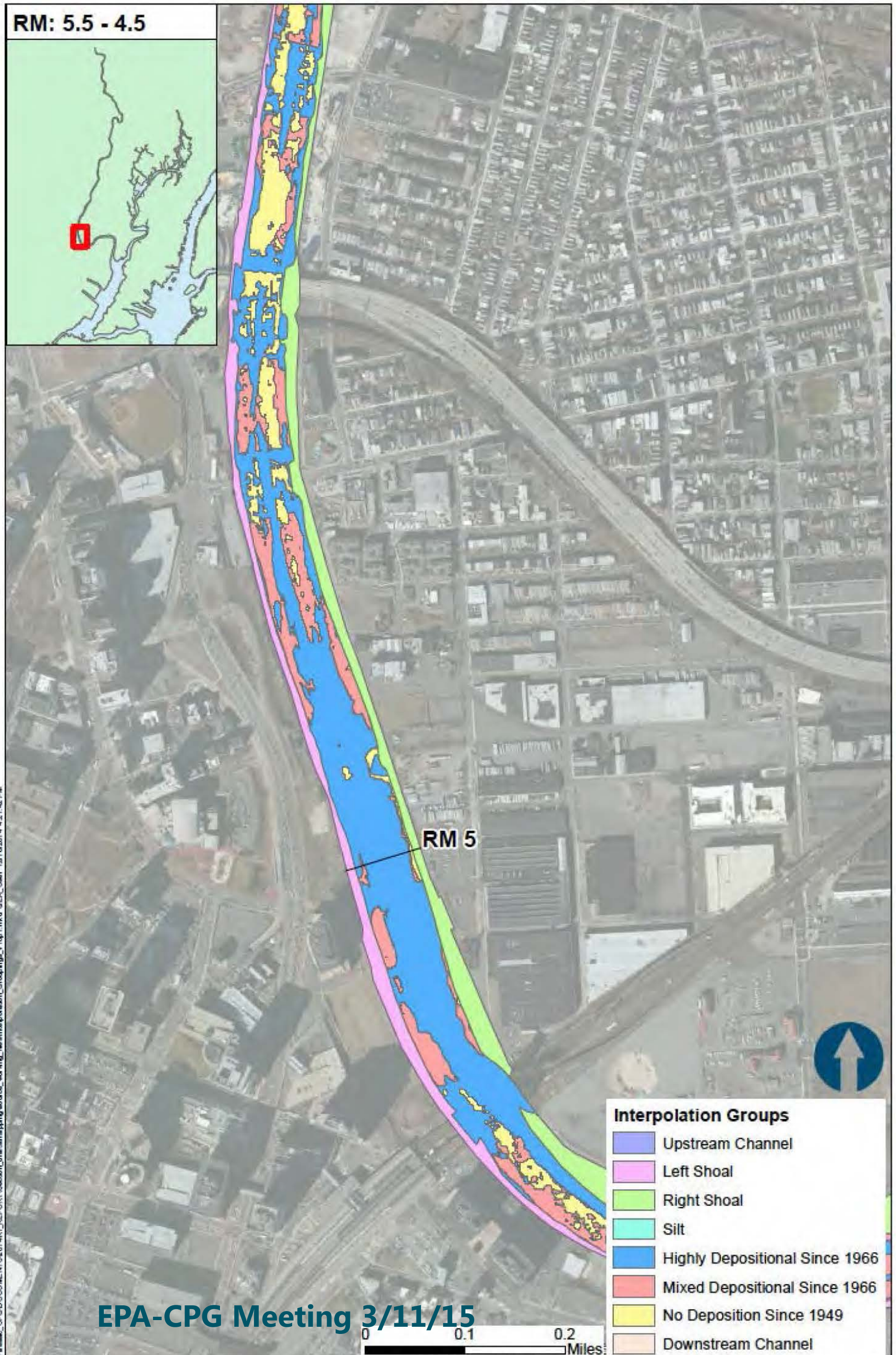
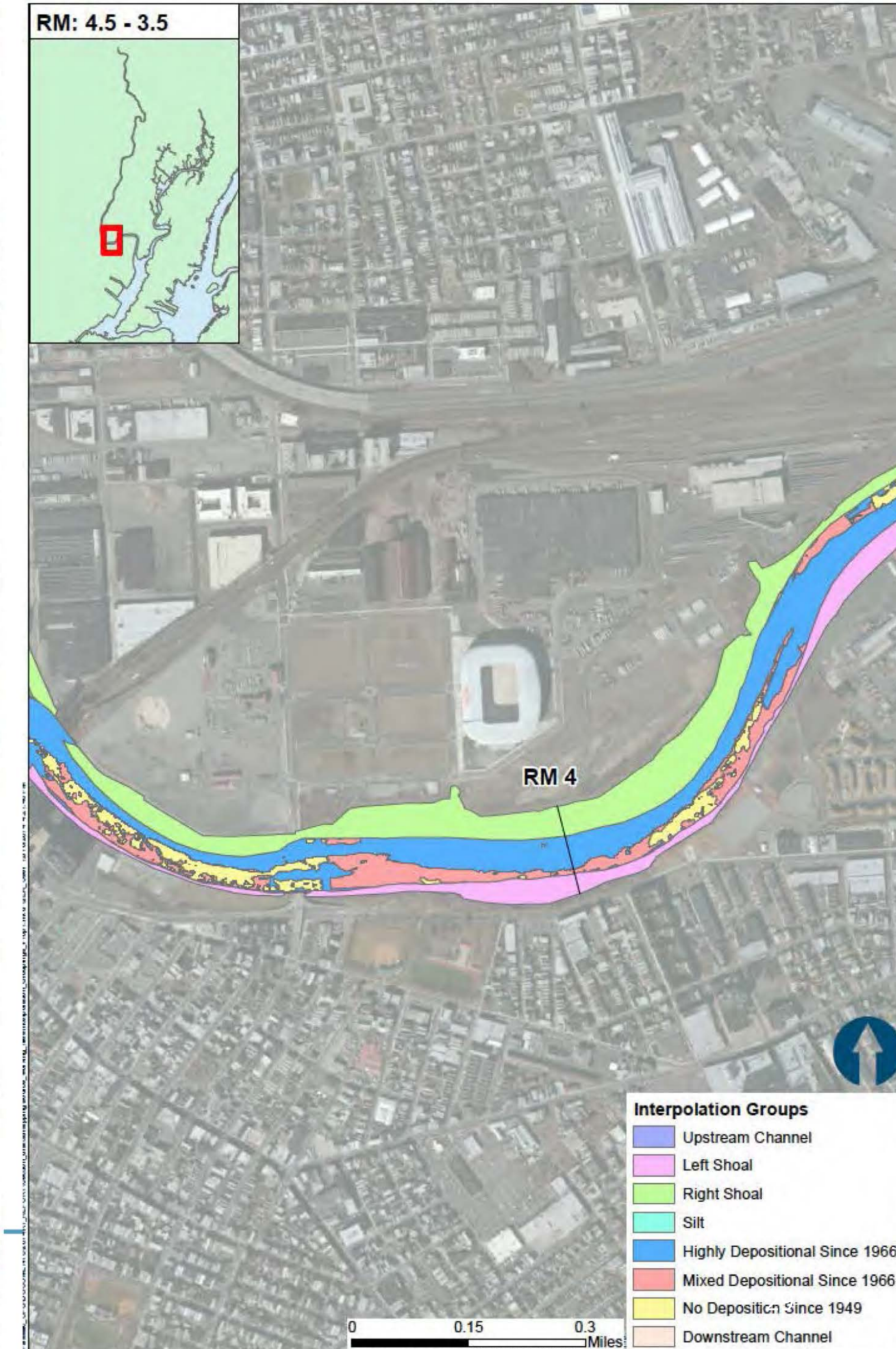


RM: 8 - 7
RM 8
Silt 1
RM 7.8
(Upstream limit of
1966 bathymetry)
RM 7
Interpolation Groups
Upstream Channel
Left Shoal
Right Shoal
Silt
Highly Depositional Since 1966
Mixed Depositional Since 1966
No Deposition Since 1949
Downstream Channel
0
0.1
0.2
Miles

RM: 7 - 5.5
RM 7
RM 6
Interpolation Groups
Upstream Channel
Left Shoal
Right Shoal
Silt
Highly Depositional Since 1966
Mixed Depositional Since 1966
No Deposition Since 1949
Downstream Channel
0
0.125
0.25
Miles

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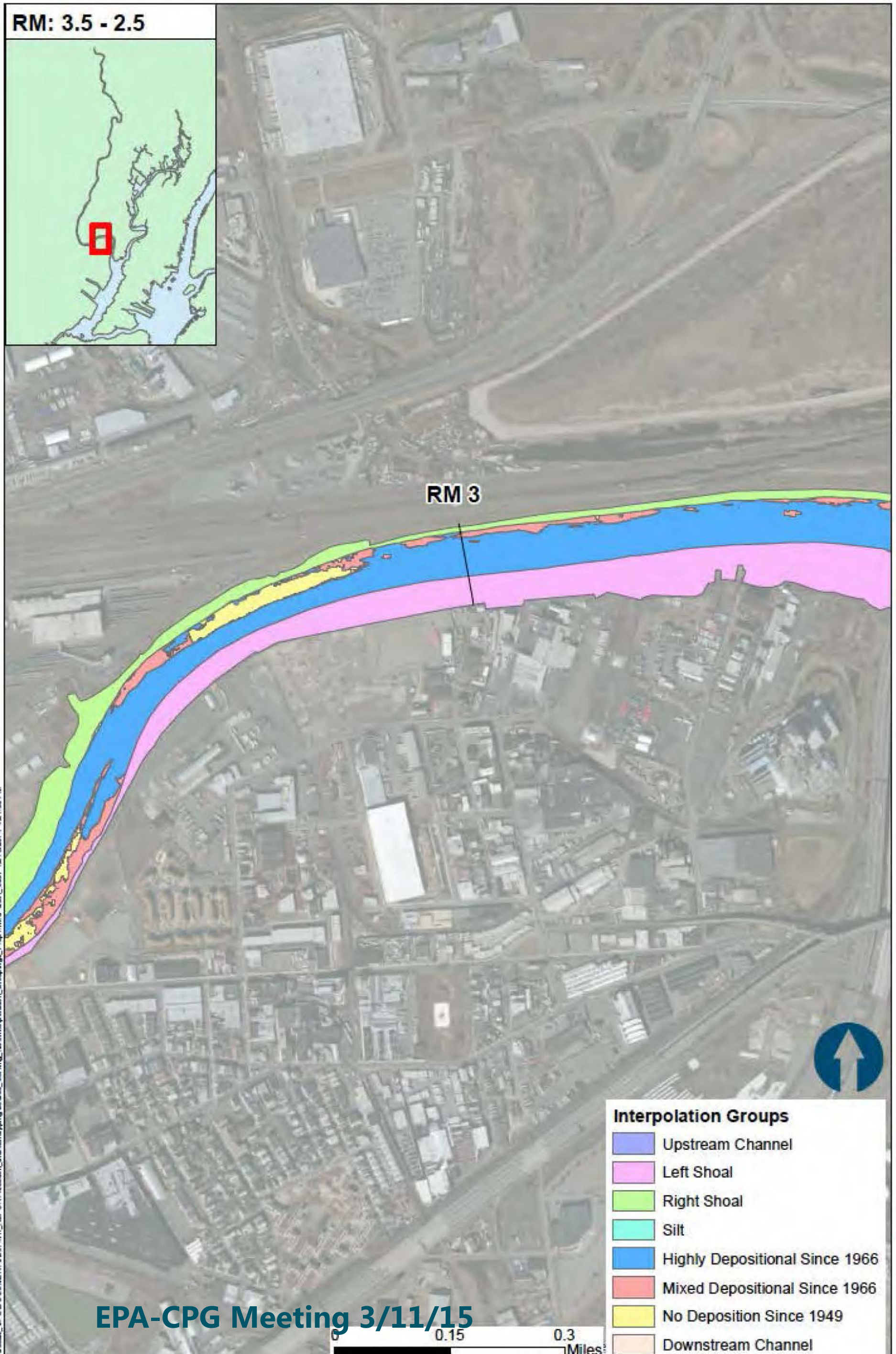
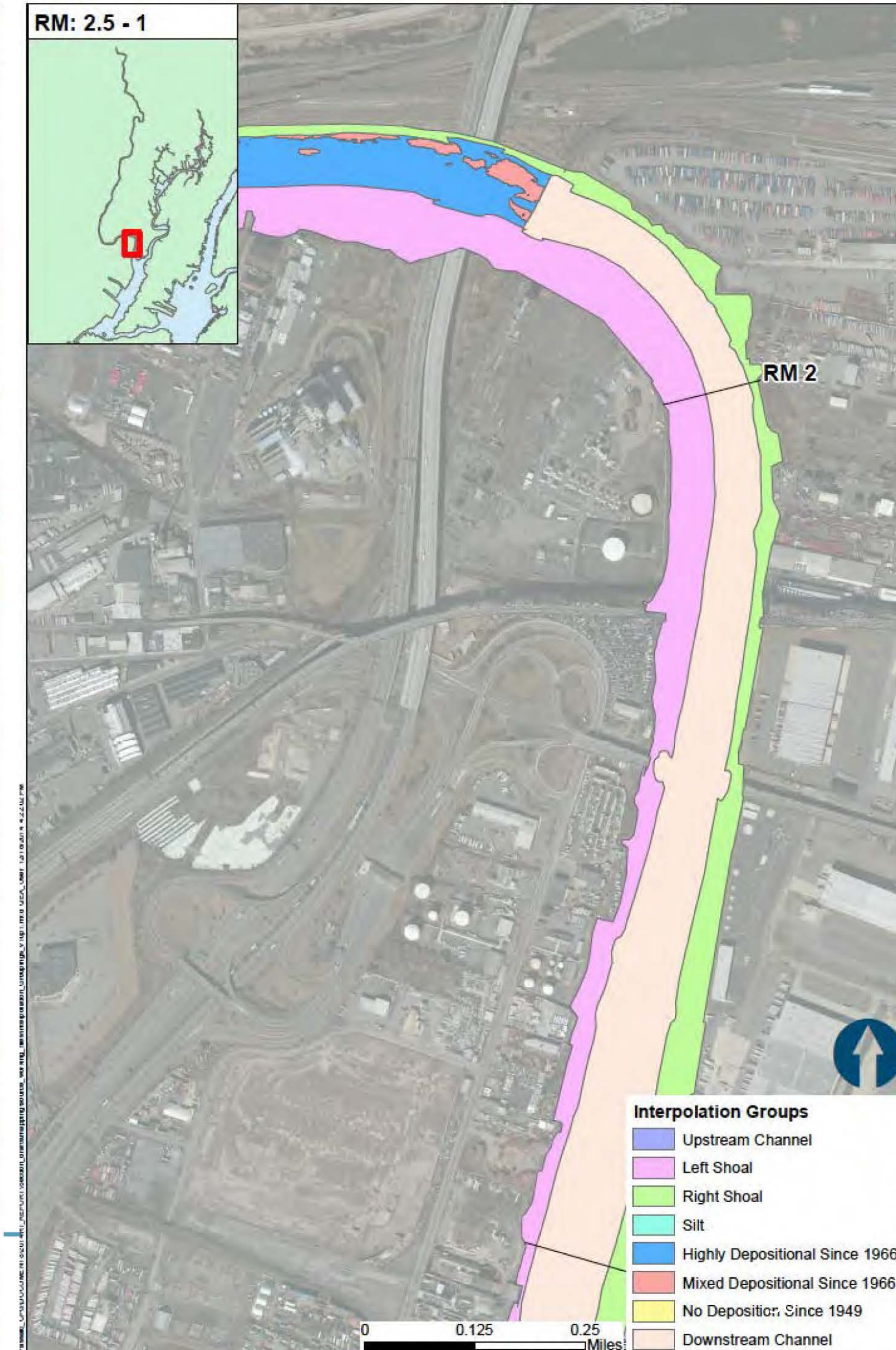

RM: 3.5 - 2.5
RM 3
Interpolation Groups
Upstream Channel
Left Shoal
Right Shoal
Silt
Highly Depositional Since 1966
Mixed Depositional Since 1966
No Deposition Since 1949
Downstream Channel
0
0.15
0.3
Miles


RM: 2.5 - 1
RM 2
Interpolation Groups
Upstream Channel
Left Shoal
Right Shoal
Silt
Highly Depositional Since 1966
Mixed Depositional Since 1966
No Deposition Since 1949
Downstream Channel
0
0.125
0.25
Miles

# Sampling Density

# Sample Count for Surface Sediments

| | RM 0 – RM 8 | RM 8 – RM 14 | RM 14 – RM 17.6 |
|---|---|---|---|
| Shoal | 114 | 50 | 5 |
| Non-dep channel | 4 | | |
| Mixed dep channel | 24 | | |
| High dep channel | 32 | | |
| Silt deposits | 4 | 64 | |
| Channel | | 71 | 24 |
| RM10.9 Silt Deposit | | 64 | |
| Downstream Channel | 24 | | |

# Samples Per Acre for 2,3,7,8-TCDD Surface Sediments

| | RM 0 – RM 8 | RM 8 – RM 14 | RM 14 – RM 17.6 |
|---|---|---|---|
| Shoal | 0.30 | 0.88 | 0.52 |
| Non-dep channel | 0.21 | | |
| Mixed dep channel | 0.48 | | |
| High dep channel | 0.29 | | |
| Silt deposits | 1.39 | 1.60 | |
| Channel | | 0.60 | 0.23 |
| RM10.9 Silt Deposit | | 4.94 | |
| Downstream Channel | 0.22 | | |

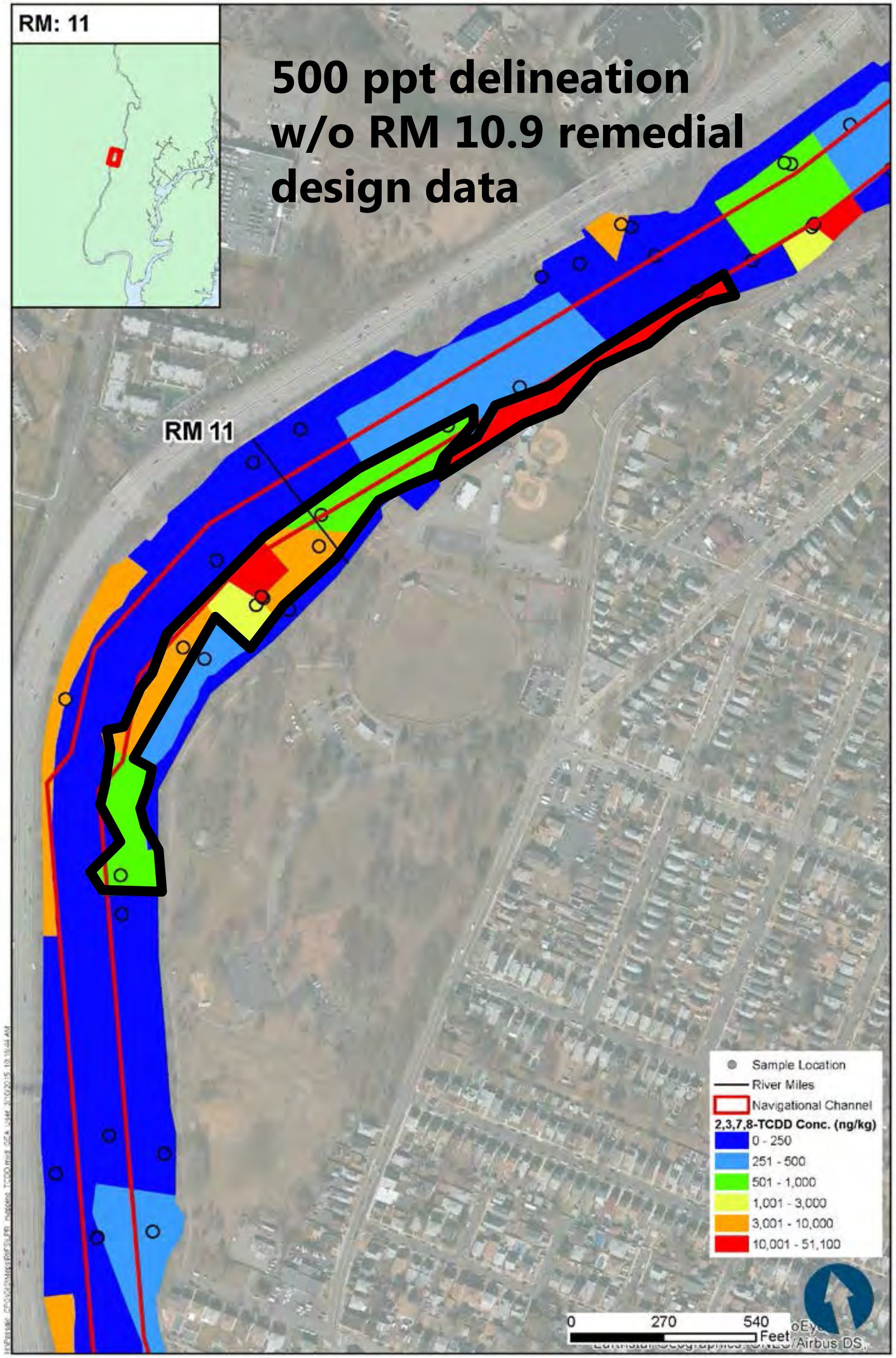
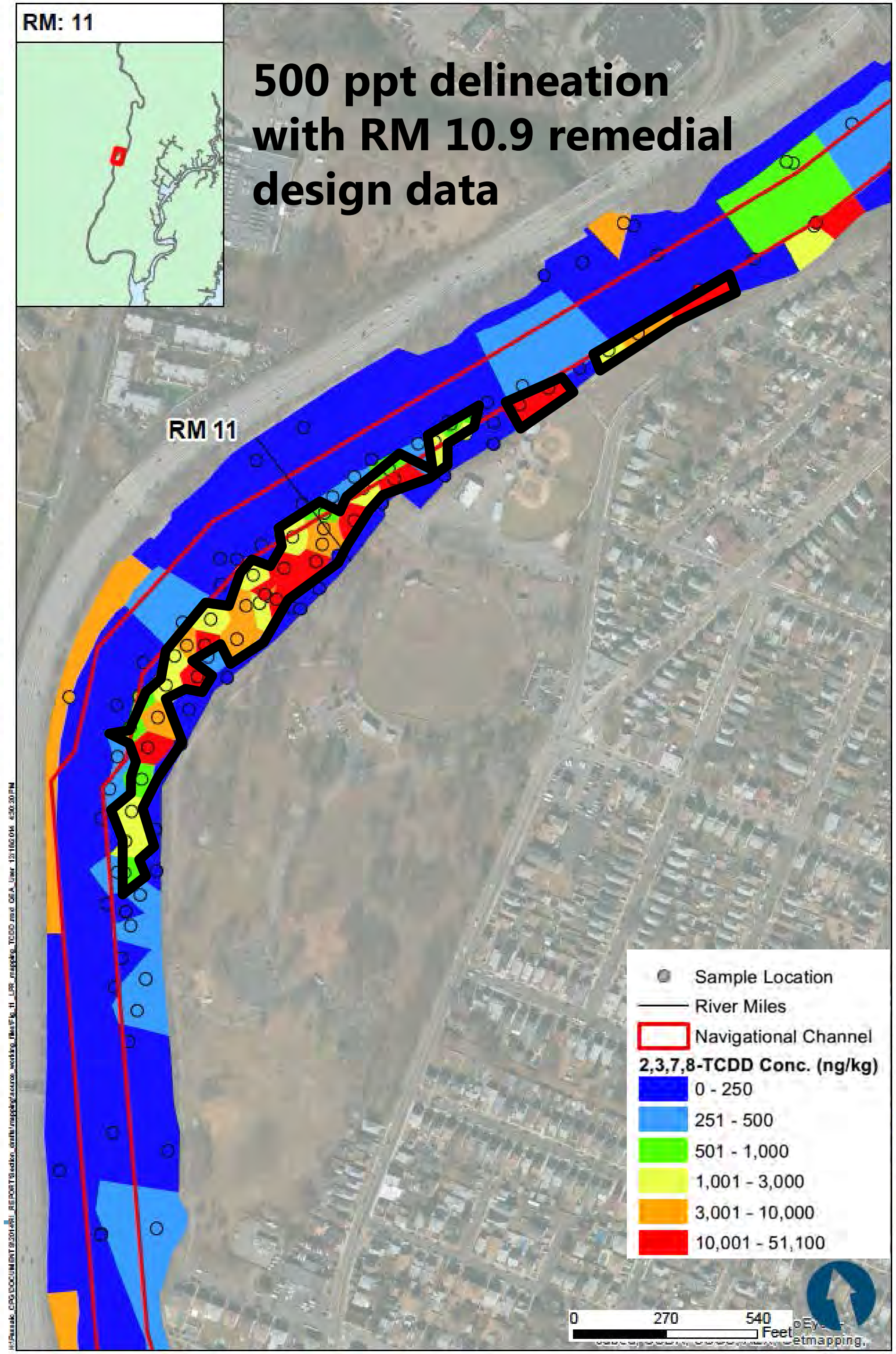
# Uncertainty

# Major Sources of Uncertainty

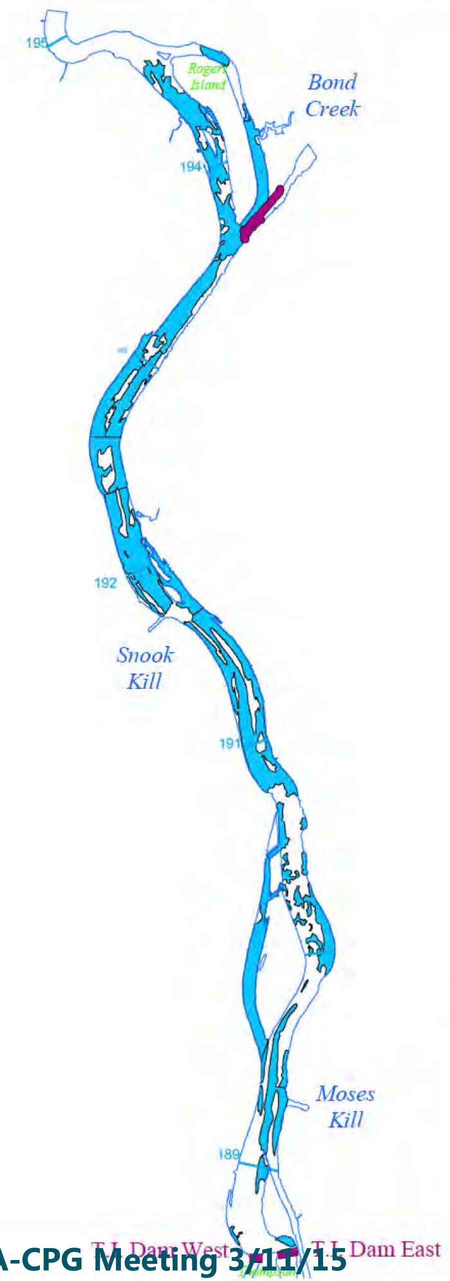
- Sparseness of the sampling locations
- Short-scale spatial variability ("noise")
- The factors that drive concentration are only approximately known
  - Erosion/deposition history
  - Sediment grain size and organic carbon content
  - Location of original sources

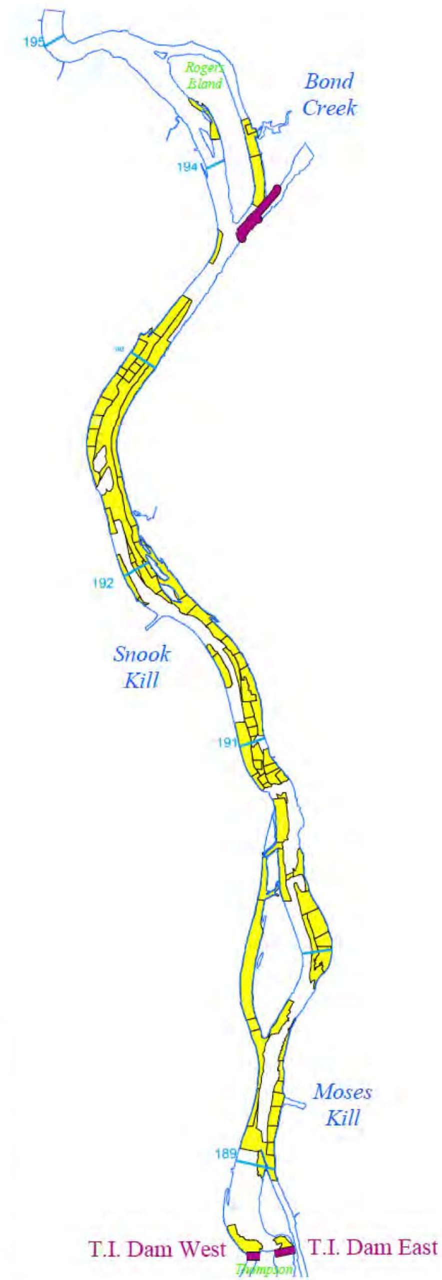
# Implications of Uncertainty

- Correlation among measured concentrations complicated by variability in factors driving concentration and imprecision of the partitioning of the river
- Any interpolation approach yields an approximate mapping of concentrations
  - Sufficient to identify regions of higher and lower concentrations
  - Sufficient for the relative evaluation of remedial alternatives


RM: 11
500 ppt delineation
w/o RM 10.9 remedial
design data
RM 11
Sample Location
River Miles
Navigational Channel
2,3,7,8-TCDD Conc. (ng/kg)
0 - 250
251 - 500
501 - 1,000
1,001 - 3,000
3,001 - 10,000
10,001 - 51,100
0
270
540
Feet

RM: 11
500 ppt delineation
with RM 10.9 remedial
design data
RM 11
Sample Location
River Miles
Navigational Channel
2,3,7,8-TCDD Conc. (ng/kg)
0 - 250
251 - 500
501 - 1,000
1,001 - 3,000
3,001 - 10,000
10,001 - 51,100
0
270
540
Feet

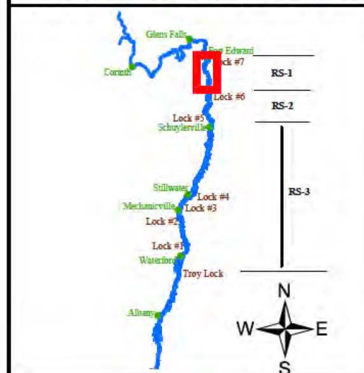
| GE Phase 1 and Phase 2 Delineation | EPA REM/3/10/Select Delineation |
|---|---|




| Total Delineated Area River Section 1 (acres) | |
|---|---|
| GE Phase 1 and Phase 2 | EPA REM/3/10/ Select |
| 311 | 266 (15) |

## LOCATOR MAP OF THE UPPER HUDSON RIVER




## GRAPHIC SCALE

0 2,700 5,400 Feet

## LEGEND

**GE Phase 1 and 2**

- Dredge Area Delineation
- Isolated Dredge Area

**EPA REM 3/10/Select**

- Dredge Area Delineation
- Shoreline
- River Miles
- Dams and Locks

*Based on the 3/8/06 GIS database file*

**General Electric Company**
**Hudson River Project**

**Comparison of GE and EPA Delineations**

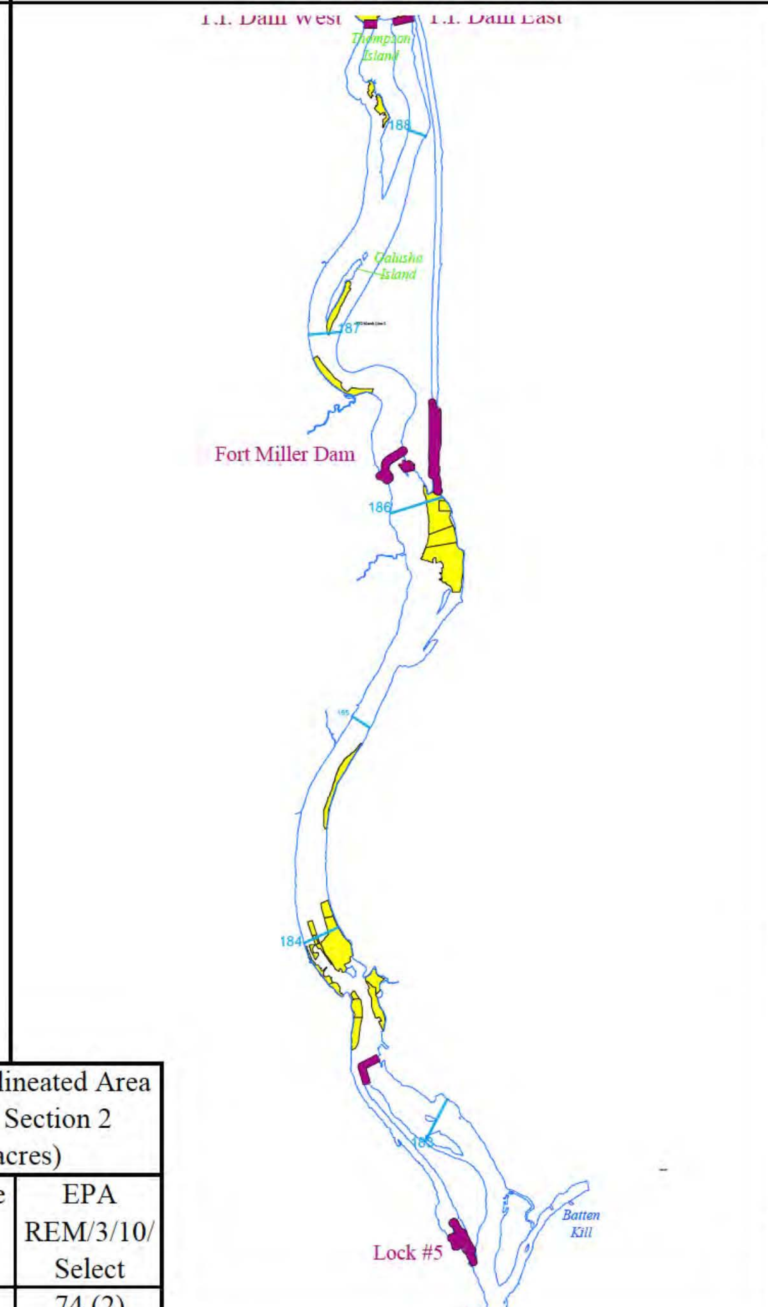
**River Section 1**

QEA

GENdad:133

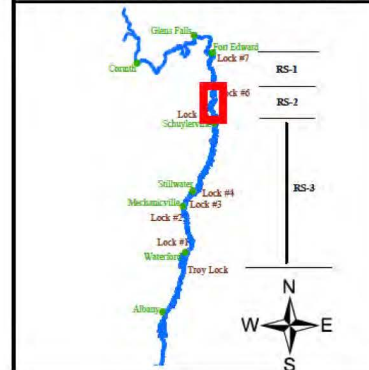
March 2006

| GE Phase 1 and Phase 2 Delineation | EPA REM/3/10/Select Delineation |
|---|---|


| Total Delineated Area River Section 2 (acres) | |
|---|---|
| GE Phase 1 and Phase 2 | EPA REM/3/10/ Select |
| 72 | 74 (2) |

## LOCATOR MAP OF THE UPPER HUDSON RIVER




## GRAPHIC SCALE

0 — 2,600 — 5,200 Feet

## LEGEND

**GE Phase 1 and 2**

- Dredge Area Delineation
- Isolated Dredge Area

**EPA REM 3/10/Select**

- Dredge Area Delineation
- Shoreline
- River Miles
- Dams and Locks

*Based on the 3/8/06 GIS database file*

**General Electric Company**
**Hudson River Project**

**Comparison of GE and EPA Delineations**

**River Section 2**

GENdad:133

March 2006

# Changes from FS to Design for Fox River OU4

- 2003 ROD specified remediation of 1,030 acres
- Basis of Design Report that included a dense pre-design sampling set specified remediation of 1,170 acres

# Mapping is Only One Source of Uncertainty

- Exposure changes resulting from remediation
  - *Concentrations in targeted areas*
  - *Concentrations outside targeted areas*
  - Post-remedy residuals
  - Effectiveness of capping
  - Recontamination from unremediated areas, dredging releases and boundaries
- Limitations of the models
  - Coarse spatial scale relative to concentration patterns and erosion/deposition behavior
  - Model error
- Imprecise assumptions about exposure, future conditions and the progress of remediation

# Dealing With Mapping Uncertainty

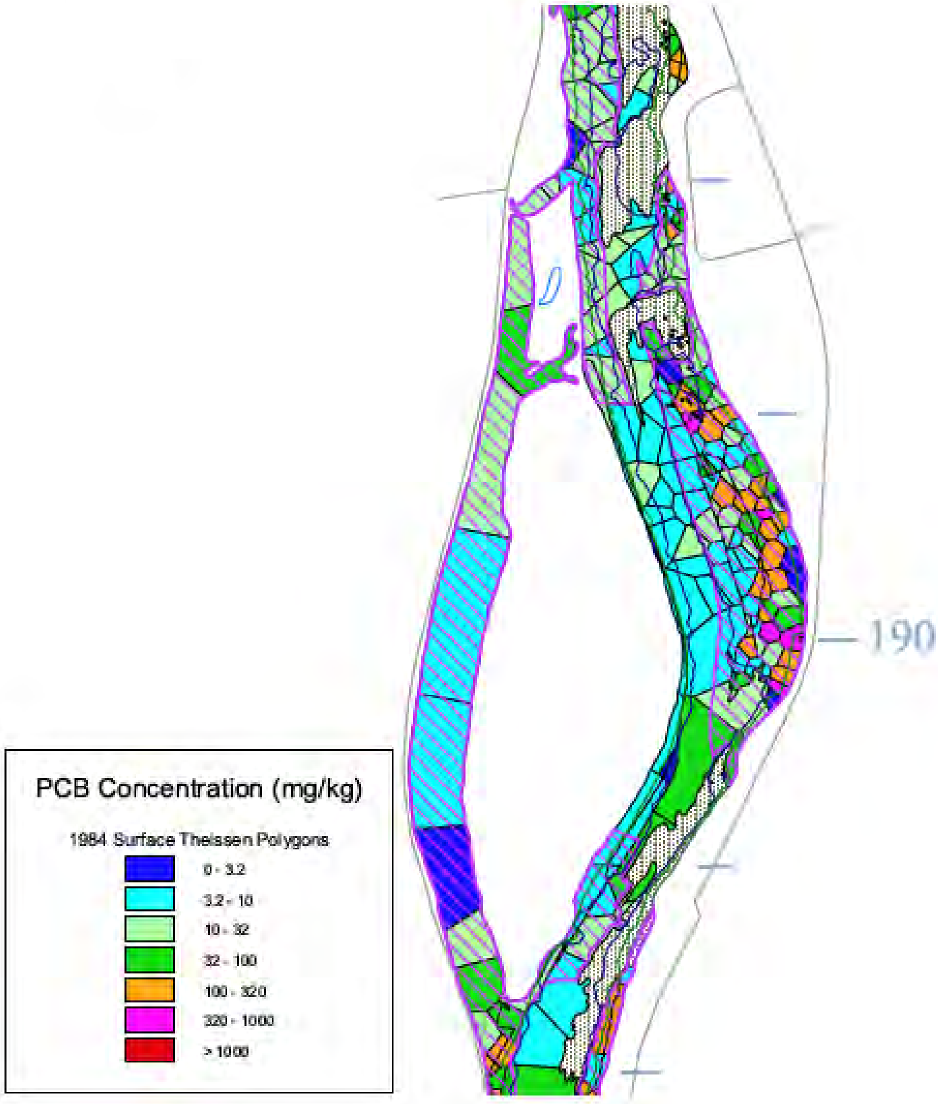
- Intensive pre-design sampling improves concentration estimates, but the other sources of uncertainty remain
- The uncertainty of remedy effectiveness is a reason for Adaptive Management
- Accounting for mapping uncertainty in the FS will not materially increase the understanding of true remedy effectiveness
  - All we really know is that the final determination of the area above a RAL will yield a result that is more or less than was specified in the FS, but experience indicates it will not be radically different

# Interpolating Within the Partitioned River Done Using Thiessen Polygons

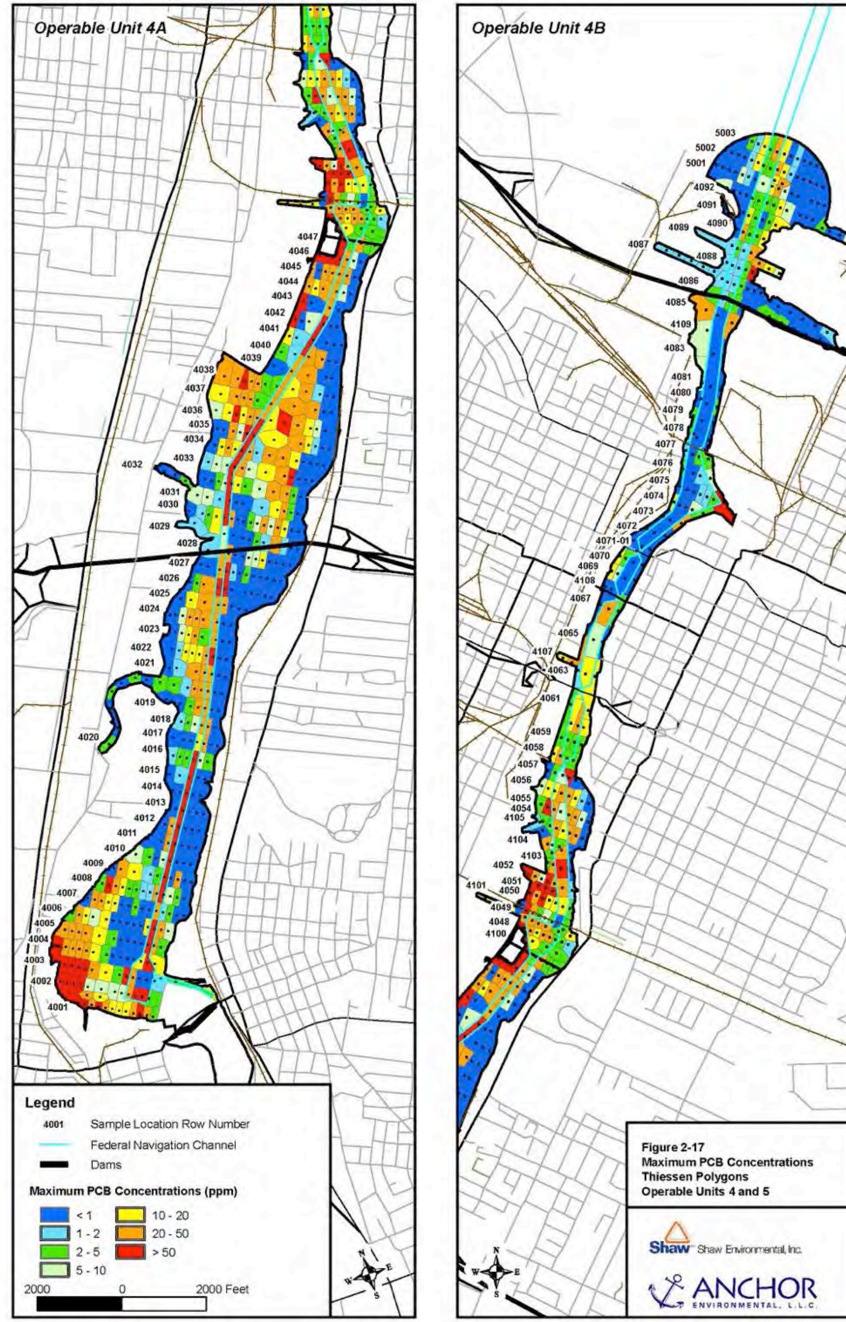
# Examples of Where Thiessen Polygons Were Used to Map Contamination

- Hudson River
- Fox River
- Lower Duwamish Waterway
- Portland Harbor
- Grasse River
- Onondaga Lake
- Buffalo River
- Housatonic River

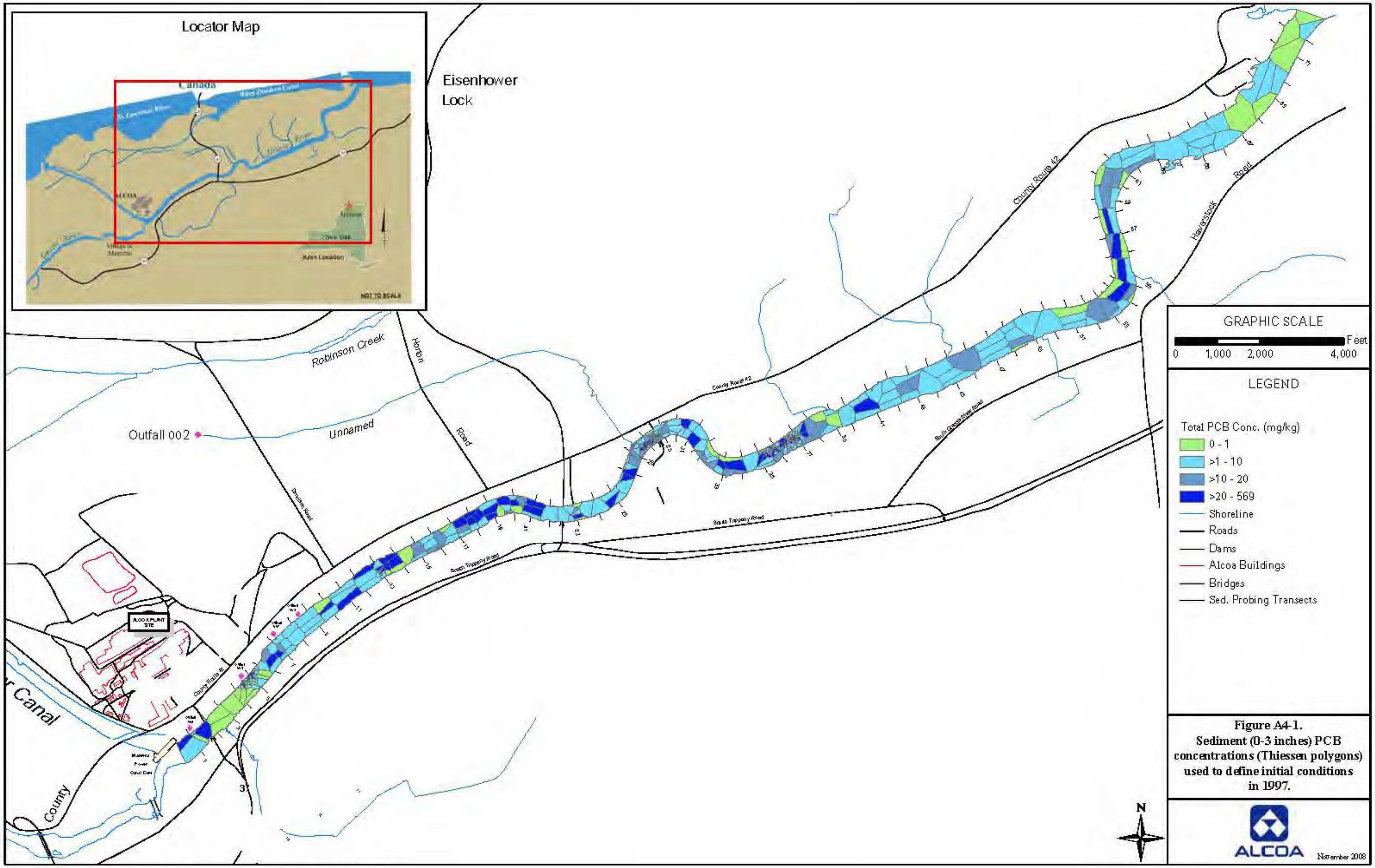
# Hudson River Feasibility Study



# Fox River Basis of Design Report



# Grasse River Analysis of Alternatives Report



# Onondaga Lake ROD

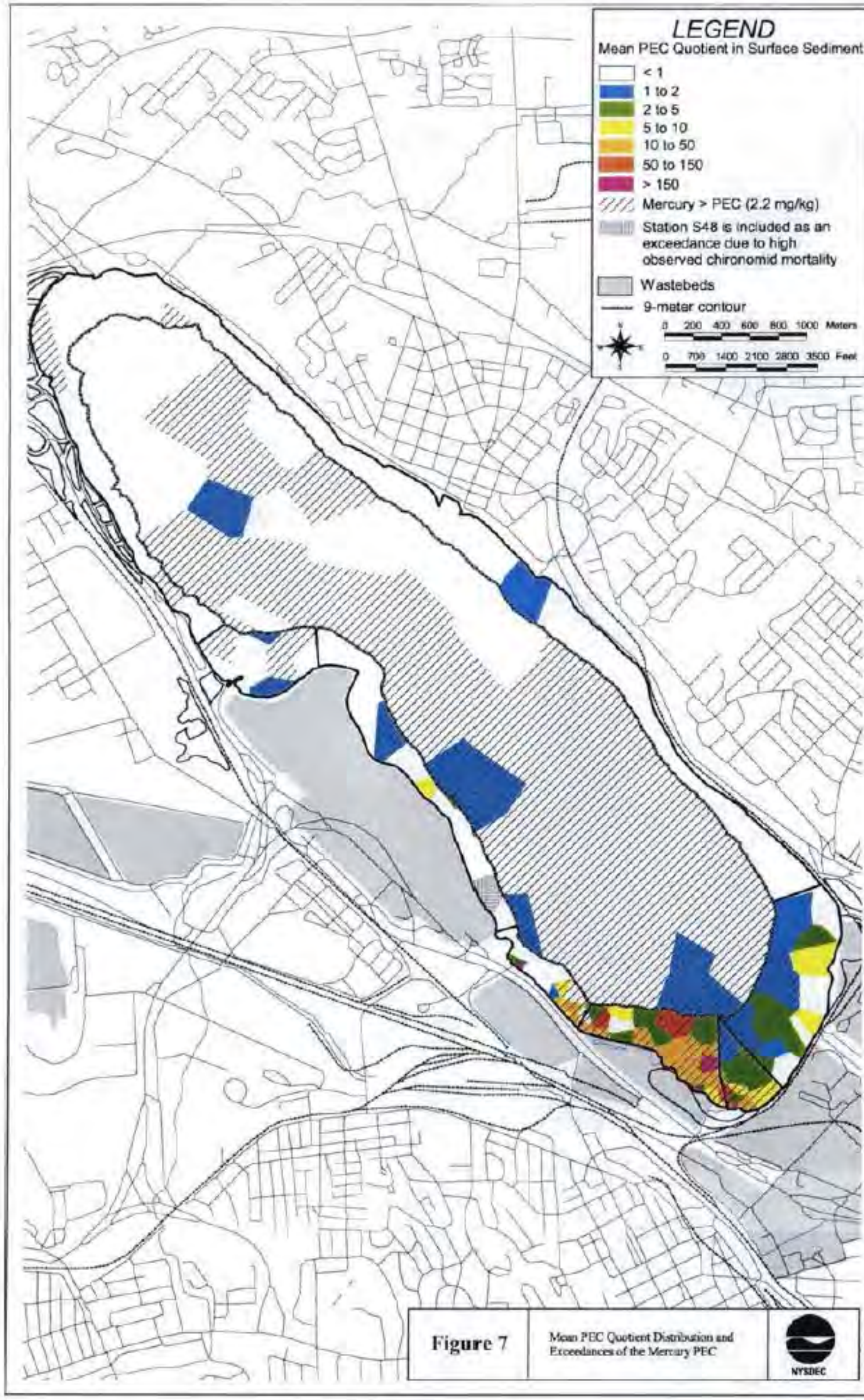
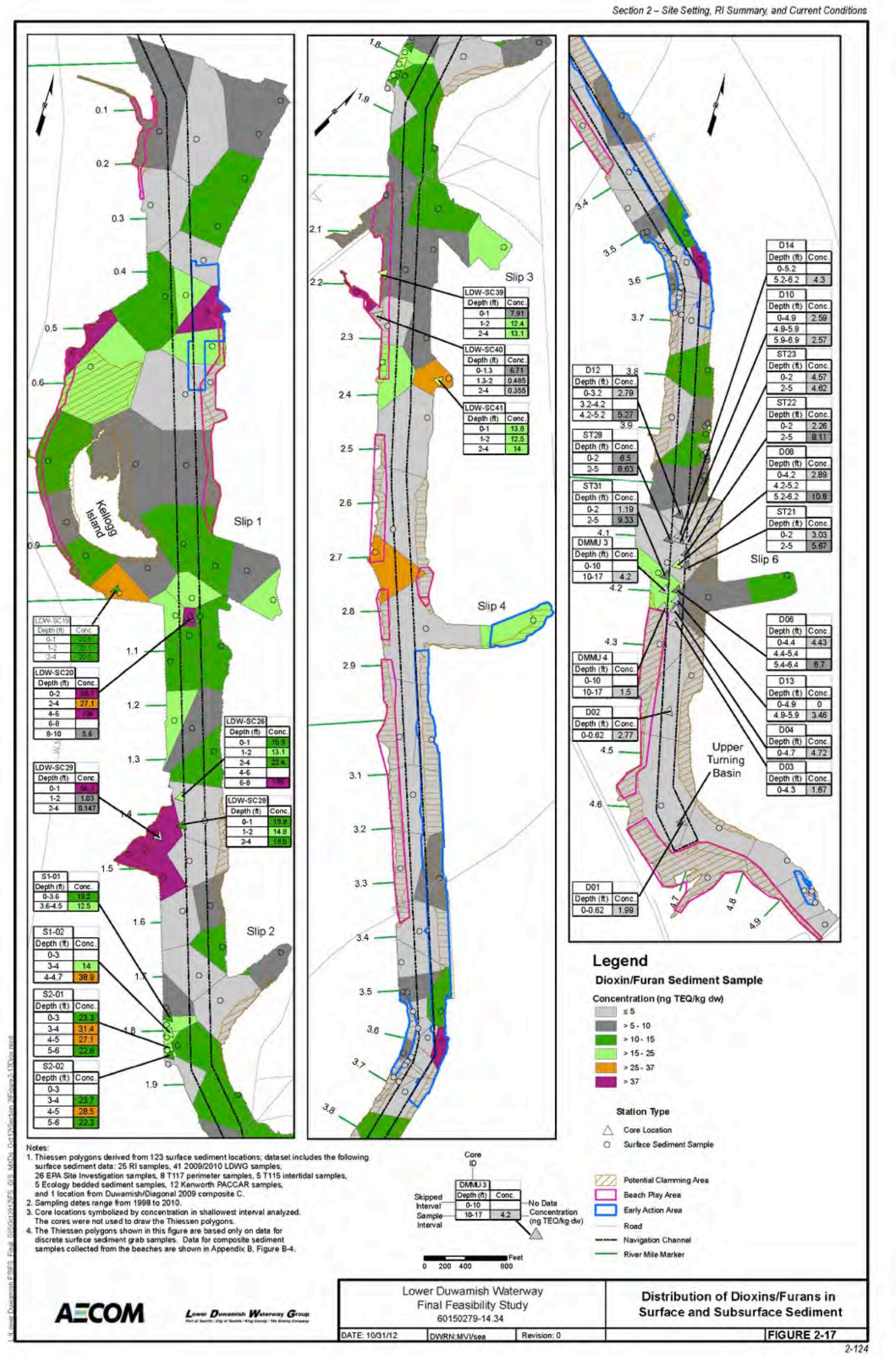


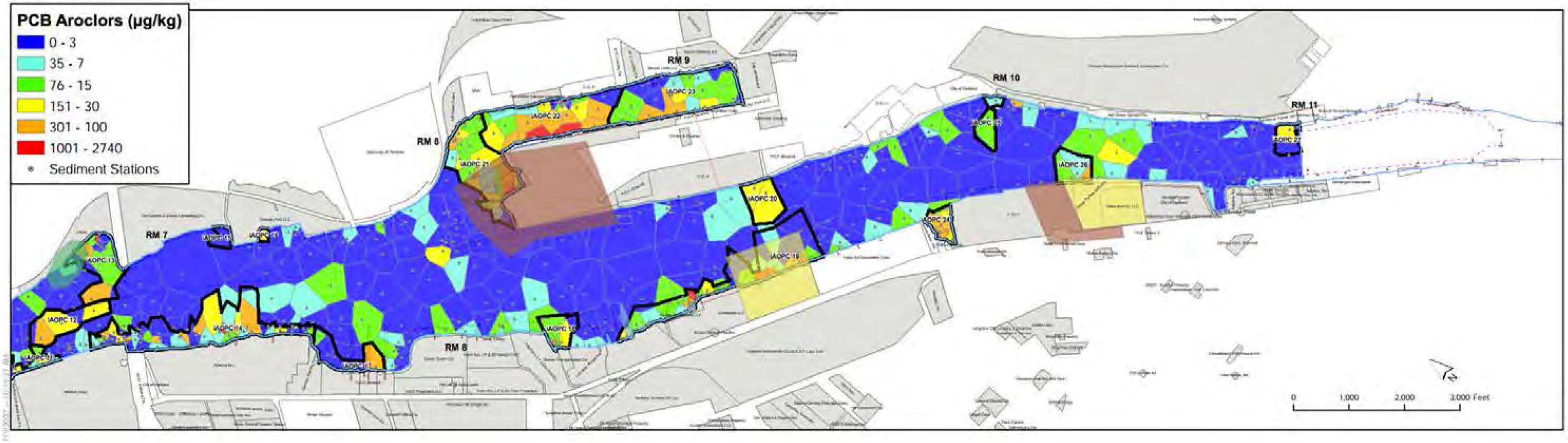

Figure 7 Mean PEC Quotient Distribution and Exceedances of the Mercury PEC

# Lower Duwamish Waterway Feasibility Study

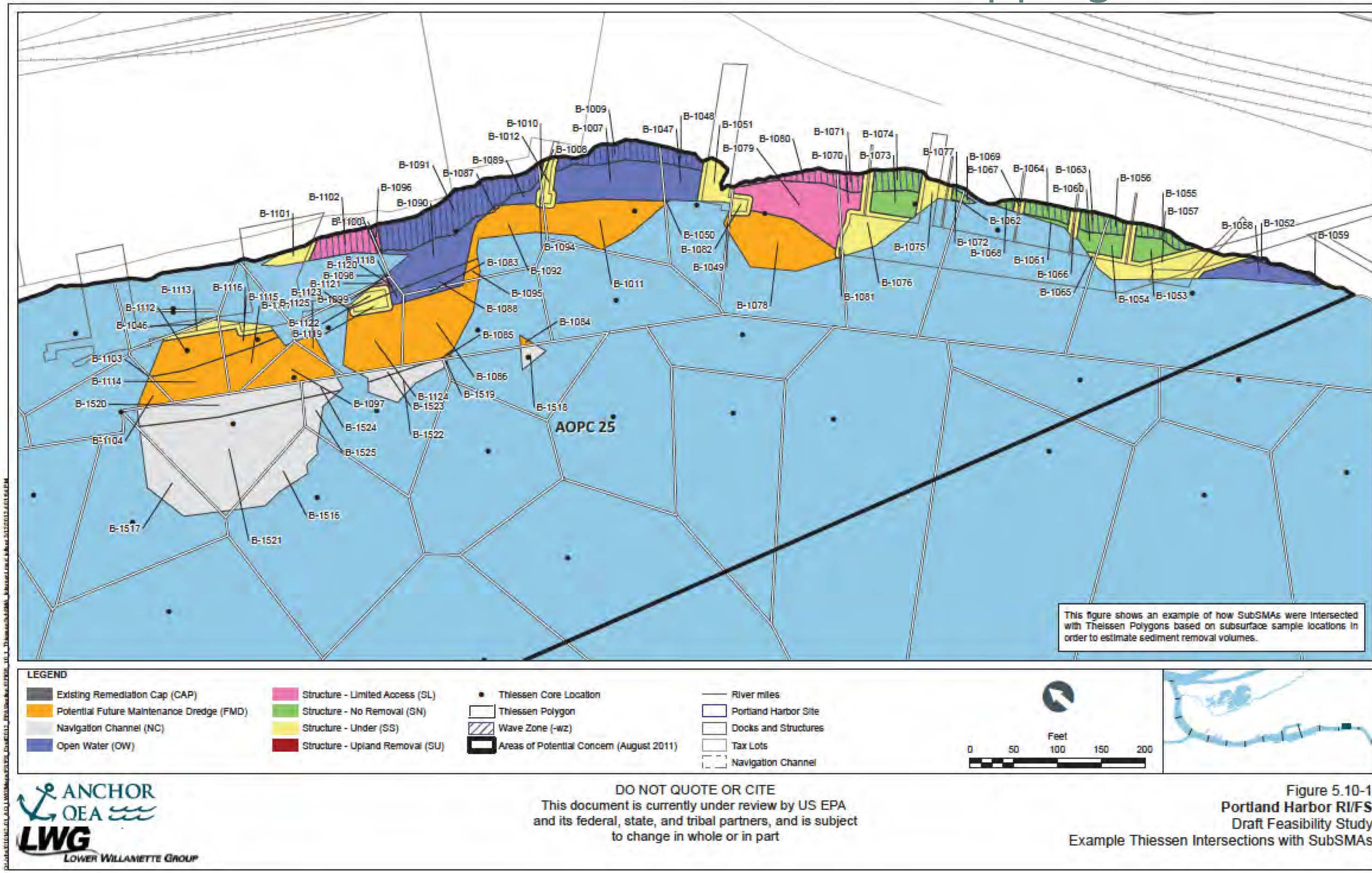
IDW used for other chemicals with much denser data sets



# Portland Harbor PCB Concentration Mapping



# Portland Harbor FS – Sediment Volume Mapping

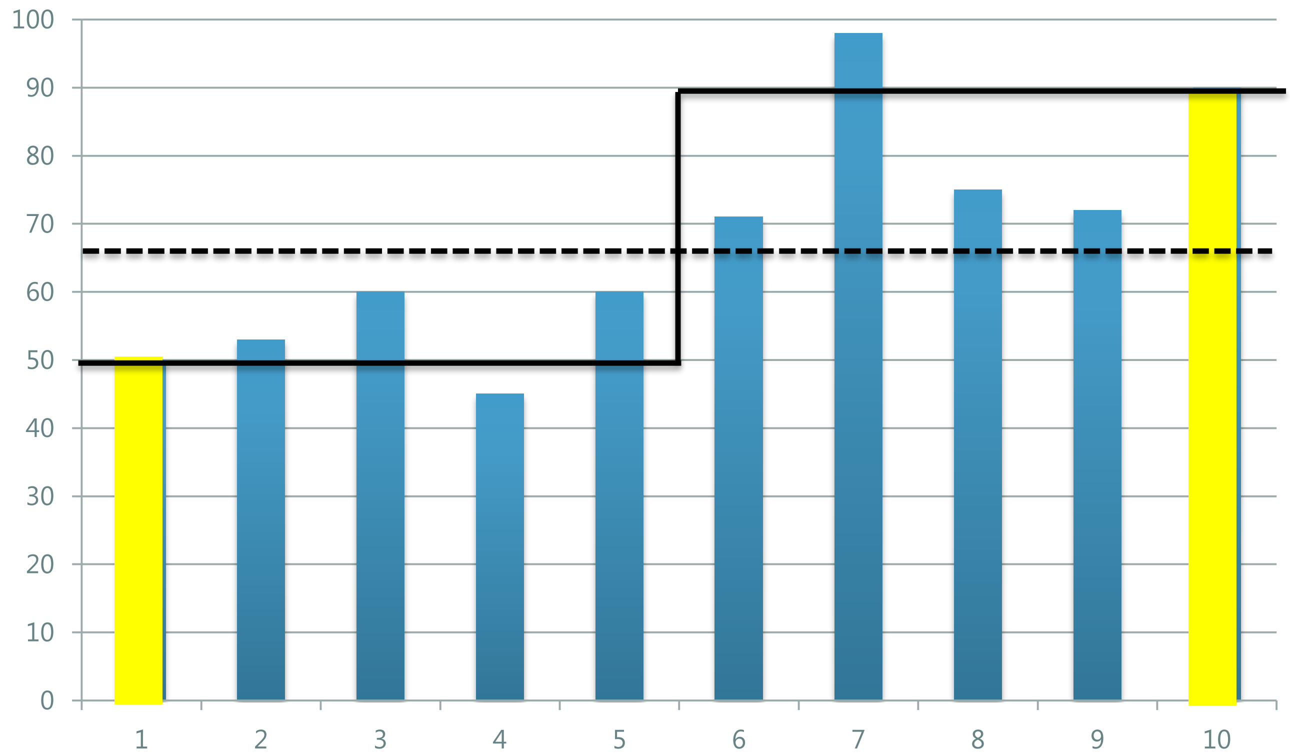


# Advantages of Thiessen Polygons

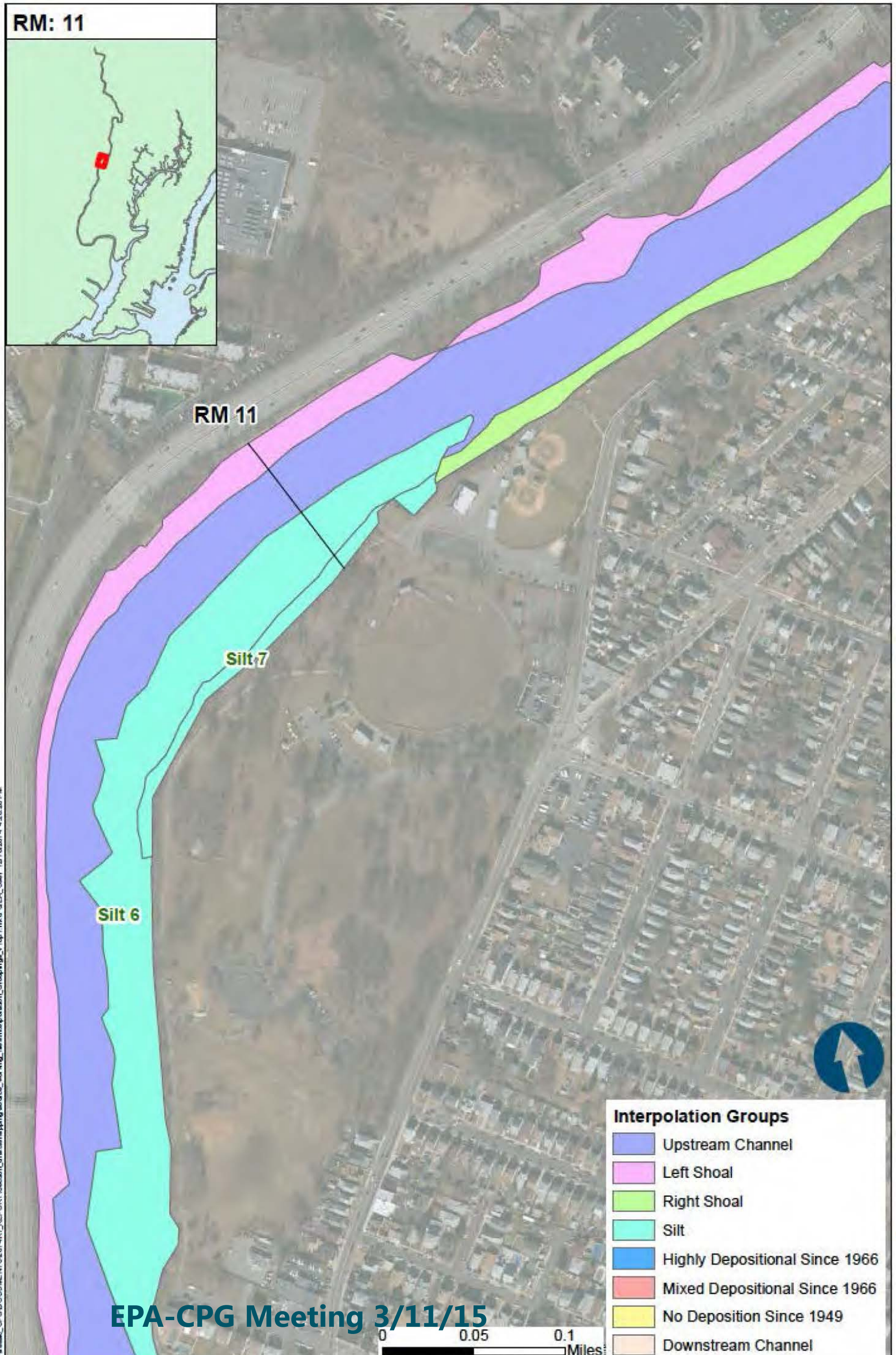
- Take account of spatial correlation, though in a limiting sense
- Reproduce the variance of the underlying data-set
  - Do not damp out the high and low parts of the concentration distribution

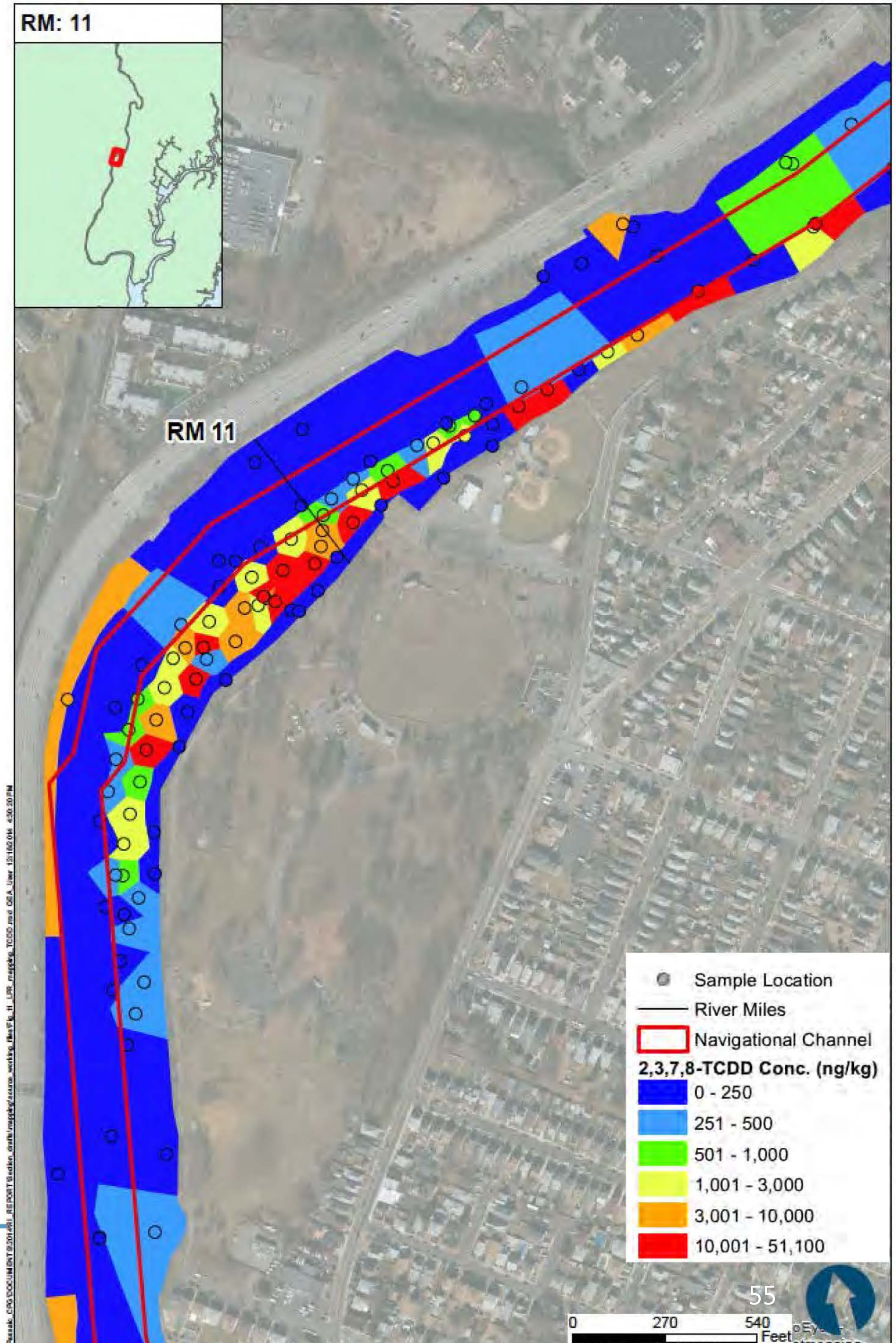
# Spatial Correlation Makes Polygons More Accurate Than Broad-Scale Averaging

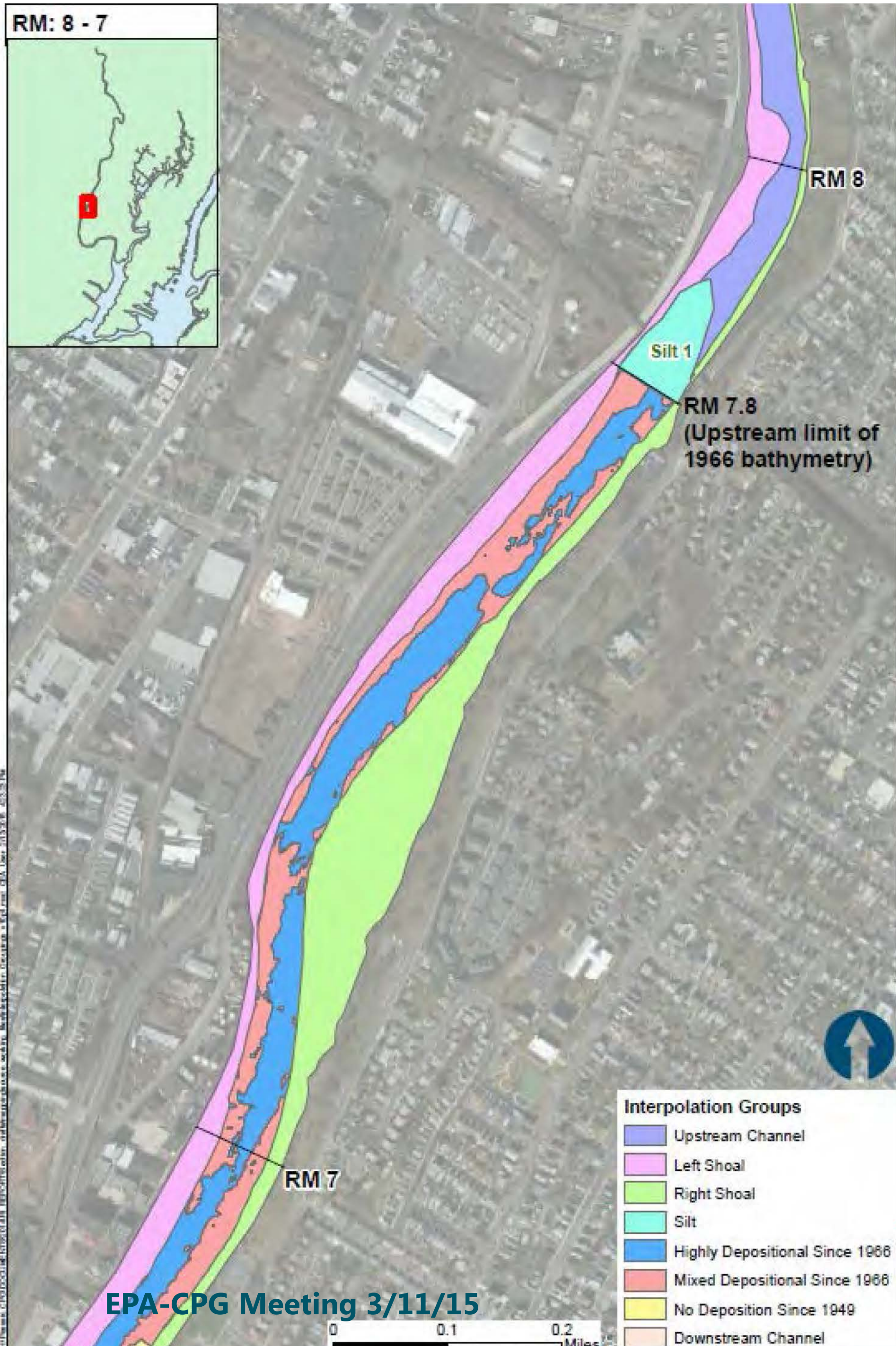
Example in which yellow locations are measured and used to interpolate between them with polygons or averaging

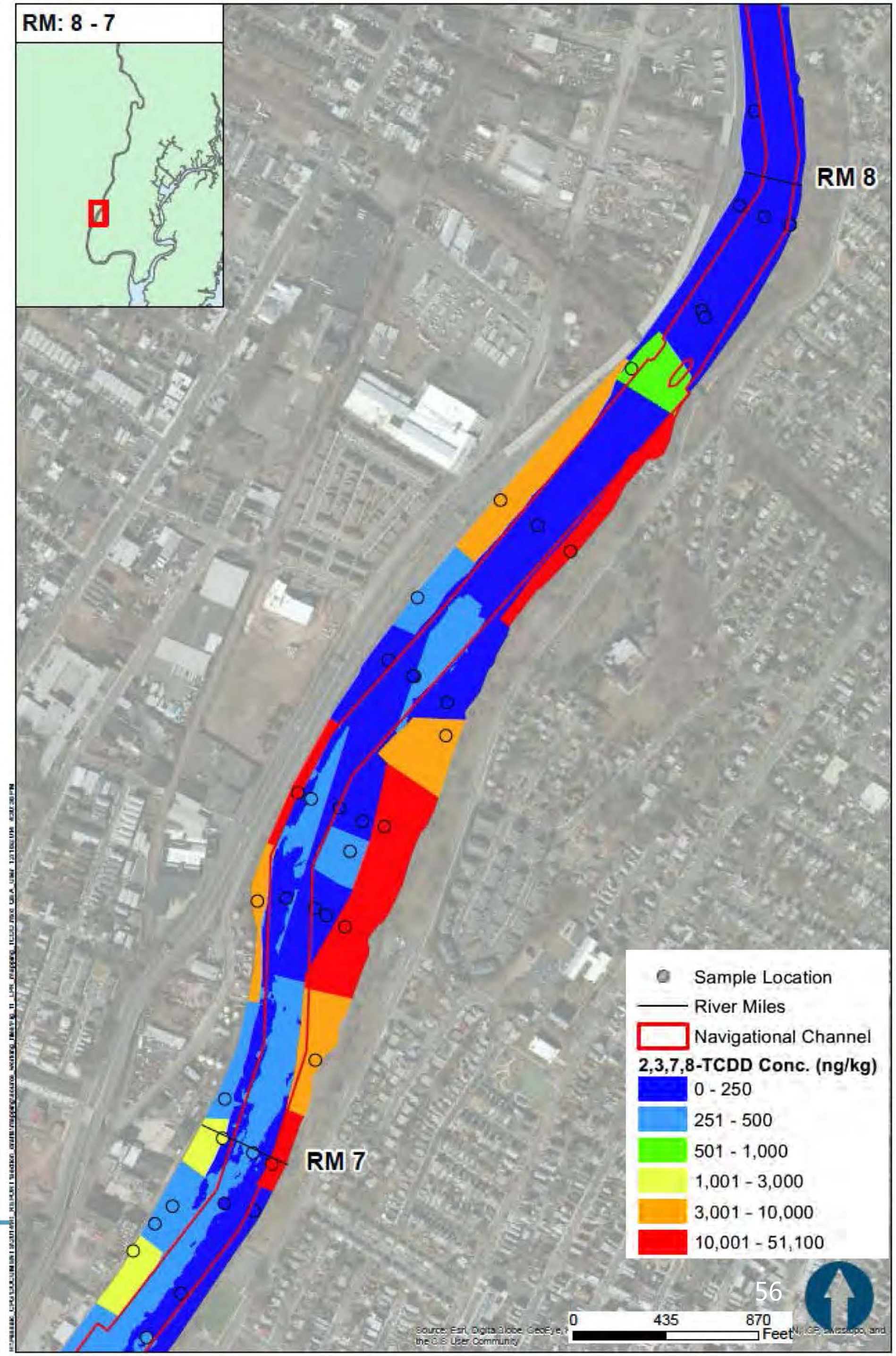


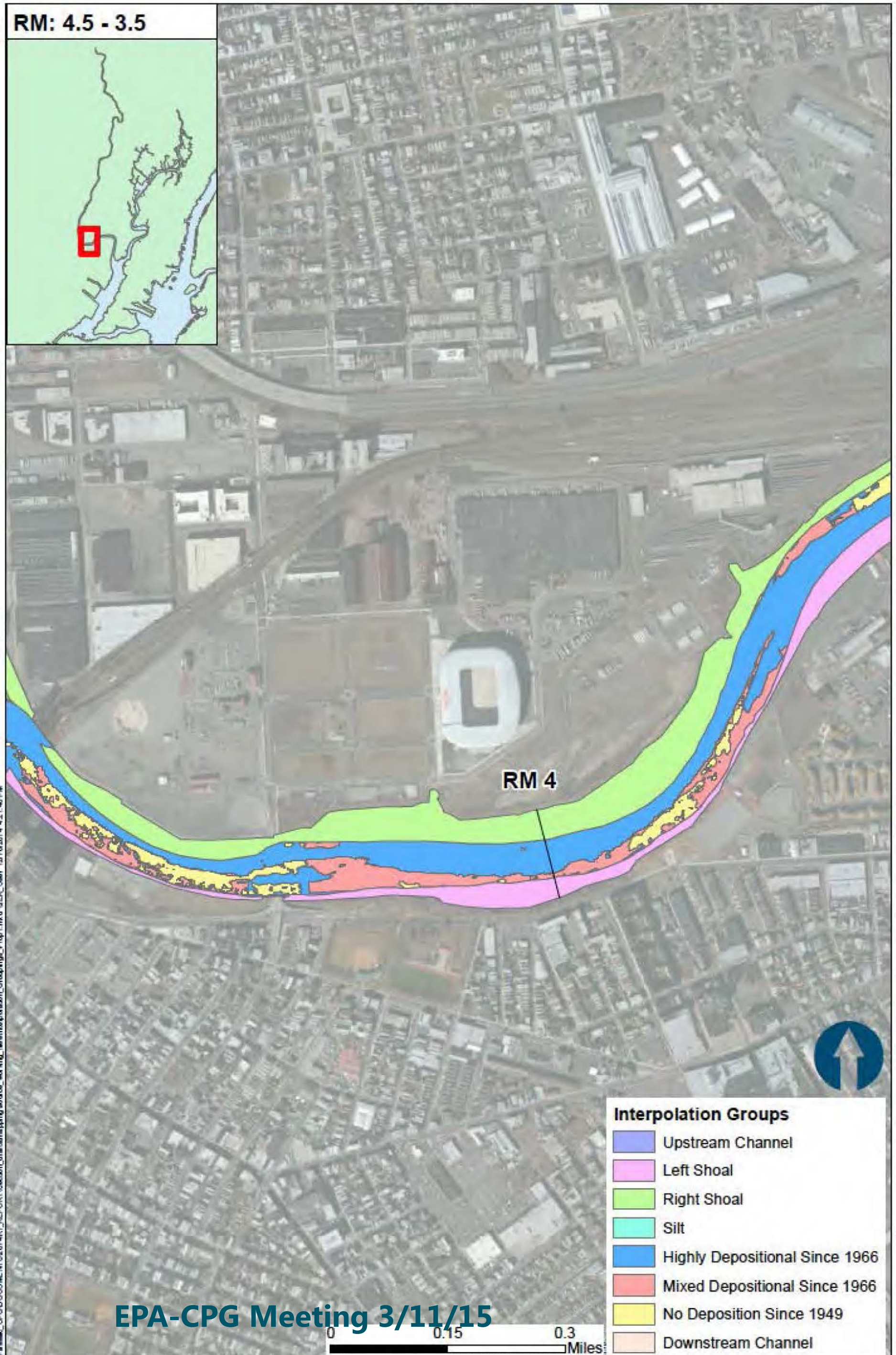
# Mapping Results

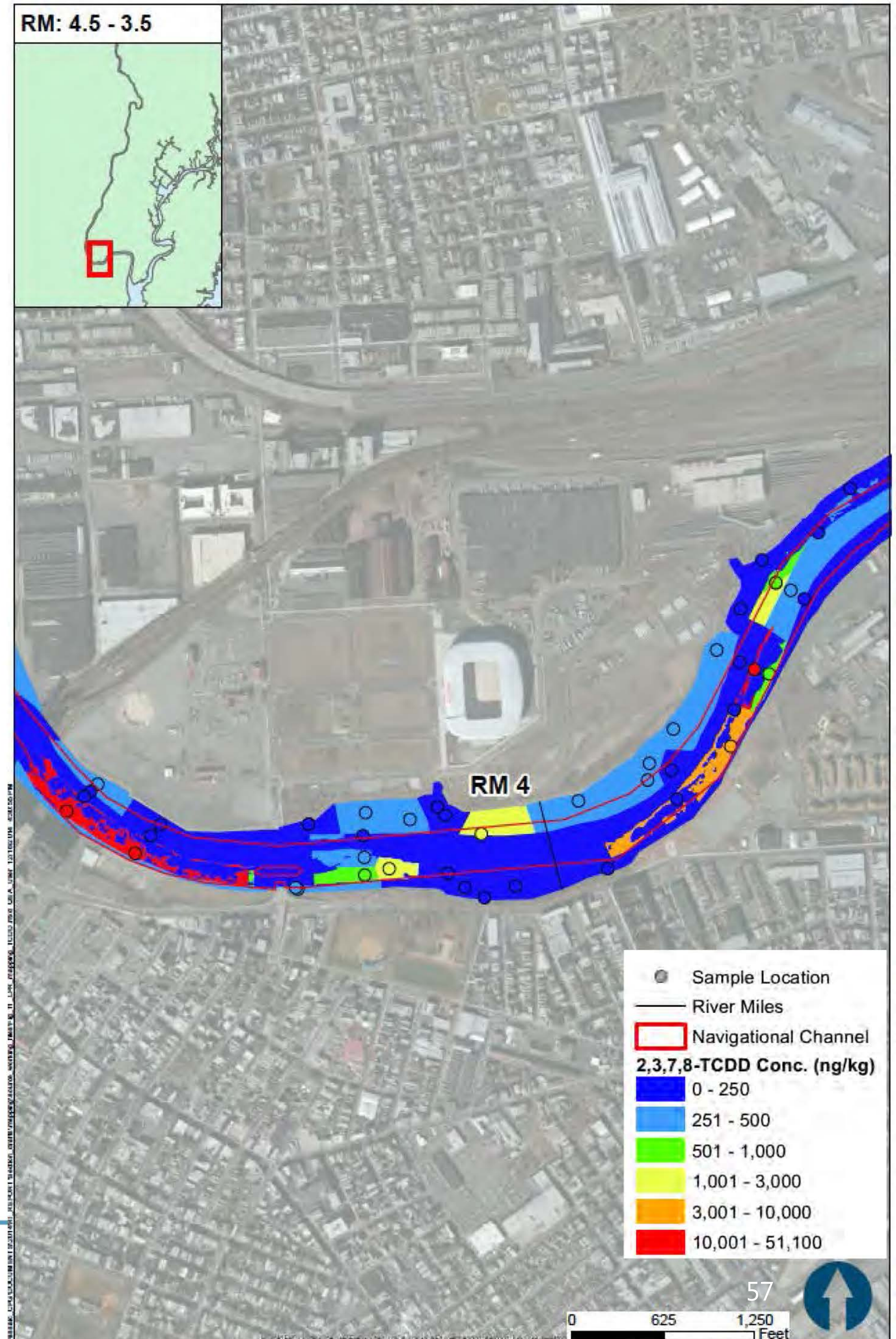

RM: 11
RM 11
Silt 7
Silt 6
Interpolation Groups
Upstream Channel
Left Shoal
Right Shoal
Silt
Highly Depositional Since 1966
Mixed Depositional Since 1966
No Deposition Since 1949
Downstream Channel
0
0.05
0.1
Miles


RM: 11
RM 11
Sample Location
River Miles
Navigational Channel
2,3,7,8-TCDD Conc. (ng/kg)
0 - 250
251 - 500
501 - 1,000
1,001 - 3,000
3,001 - 10,000
10,001 - 51,100
0
270
540
Feet


RM: 8 - 7
RM 8
Silt 1
RM 7.8
(Upstream limit of
1966 bathymetry)
RM 7
Interpolation Groups
Upstream Channel
Left Shoal
Right Shoal
Silt
Highly Depositional Since 1966
Mixed Depositional Since 1966
No Deposition Since 1949
Downstream Channel
0
0.1
0.2
Miles


RM: 8 - 7
RM 8
RM 7
Sample Location
River Miles
Navigational Channel
2,3,7,8-TCDD Conc. (ng/kg)
0 - 250
251 - 500
501 - 1,000
1,001 - 3,000
3,001 - 10,000
10,001 - 51,100
0
435
870
Feet

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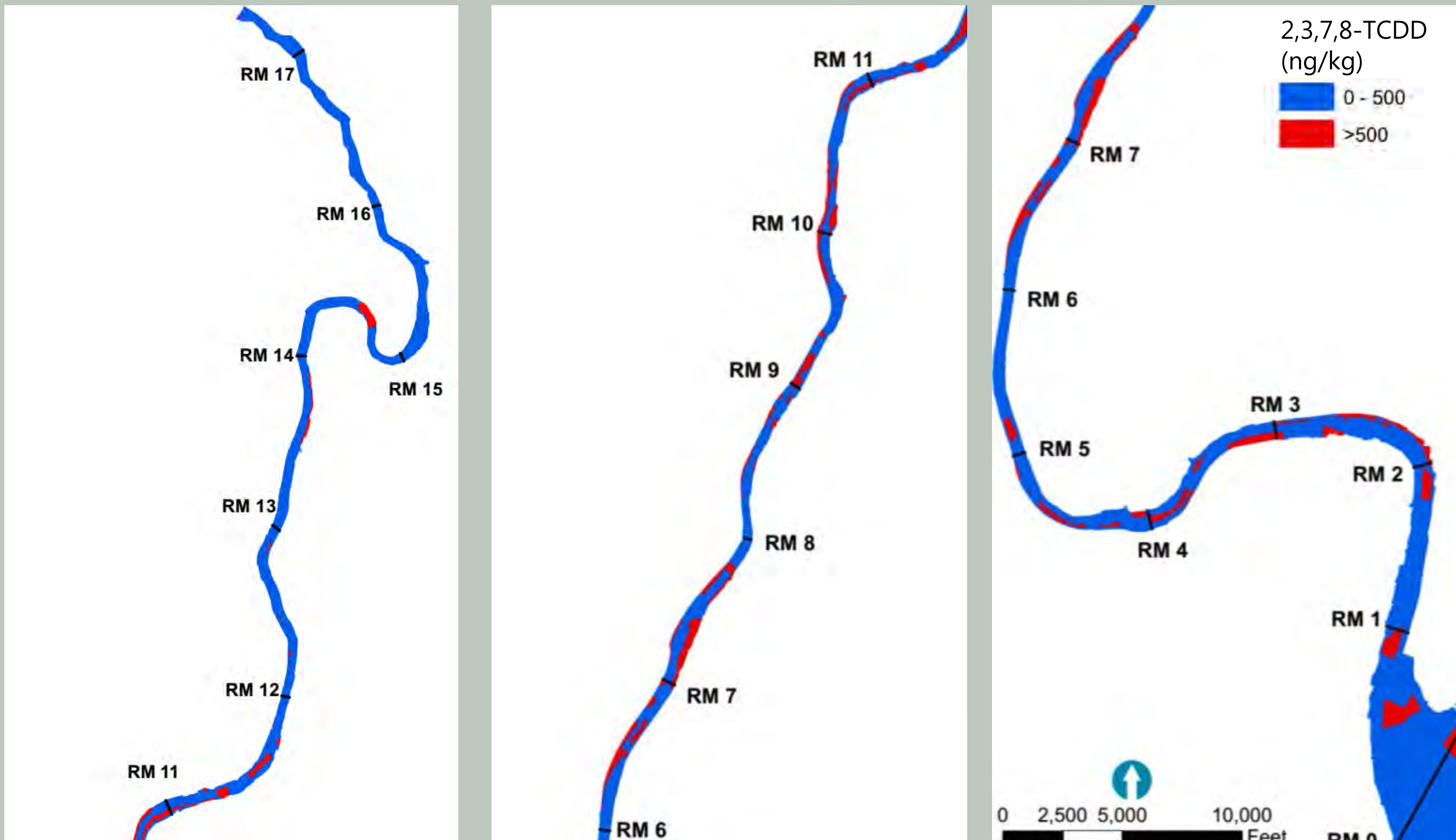
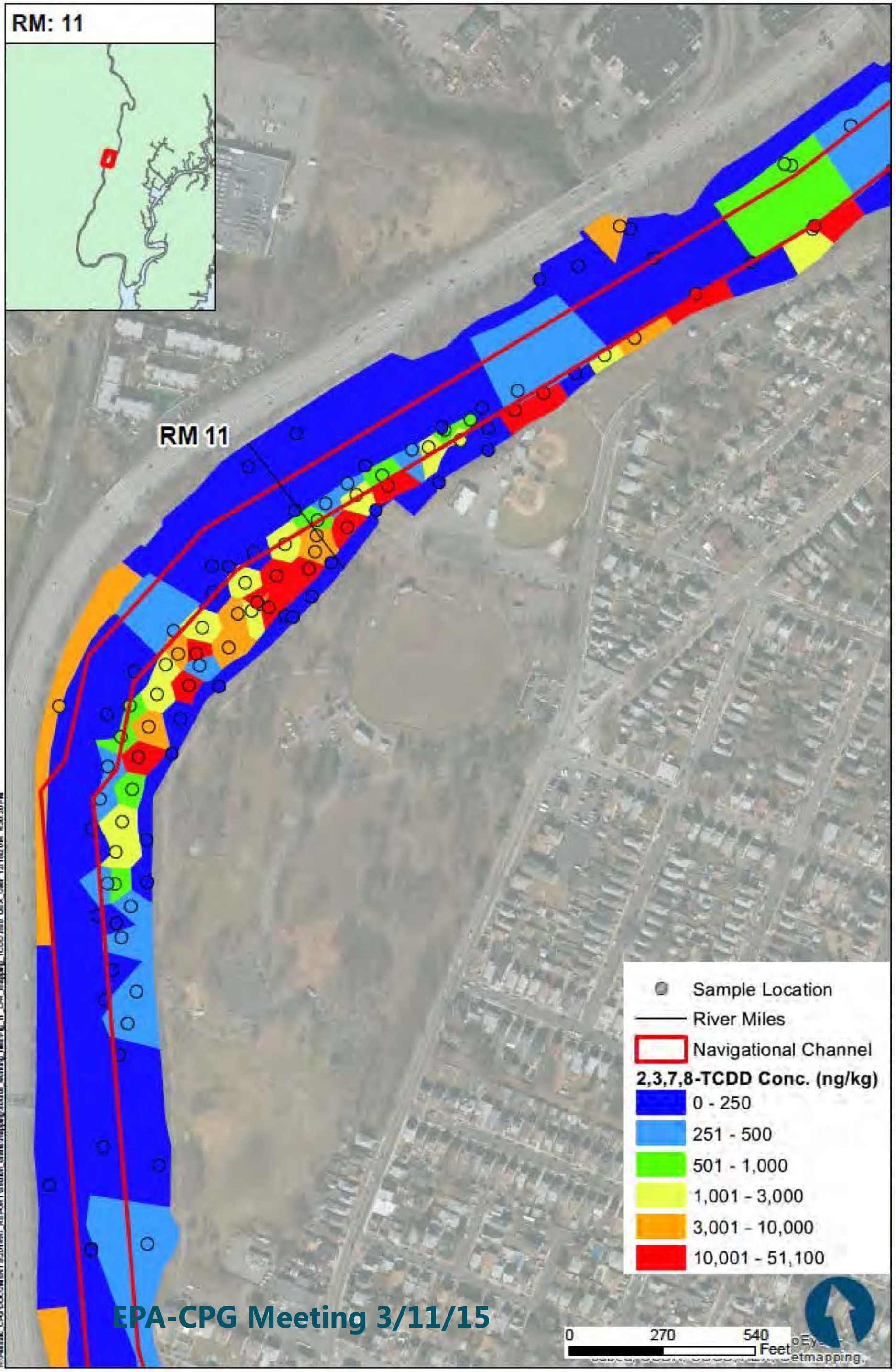
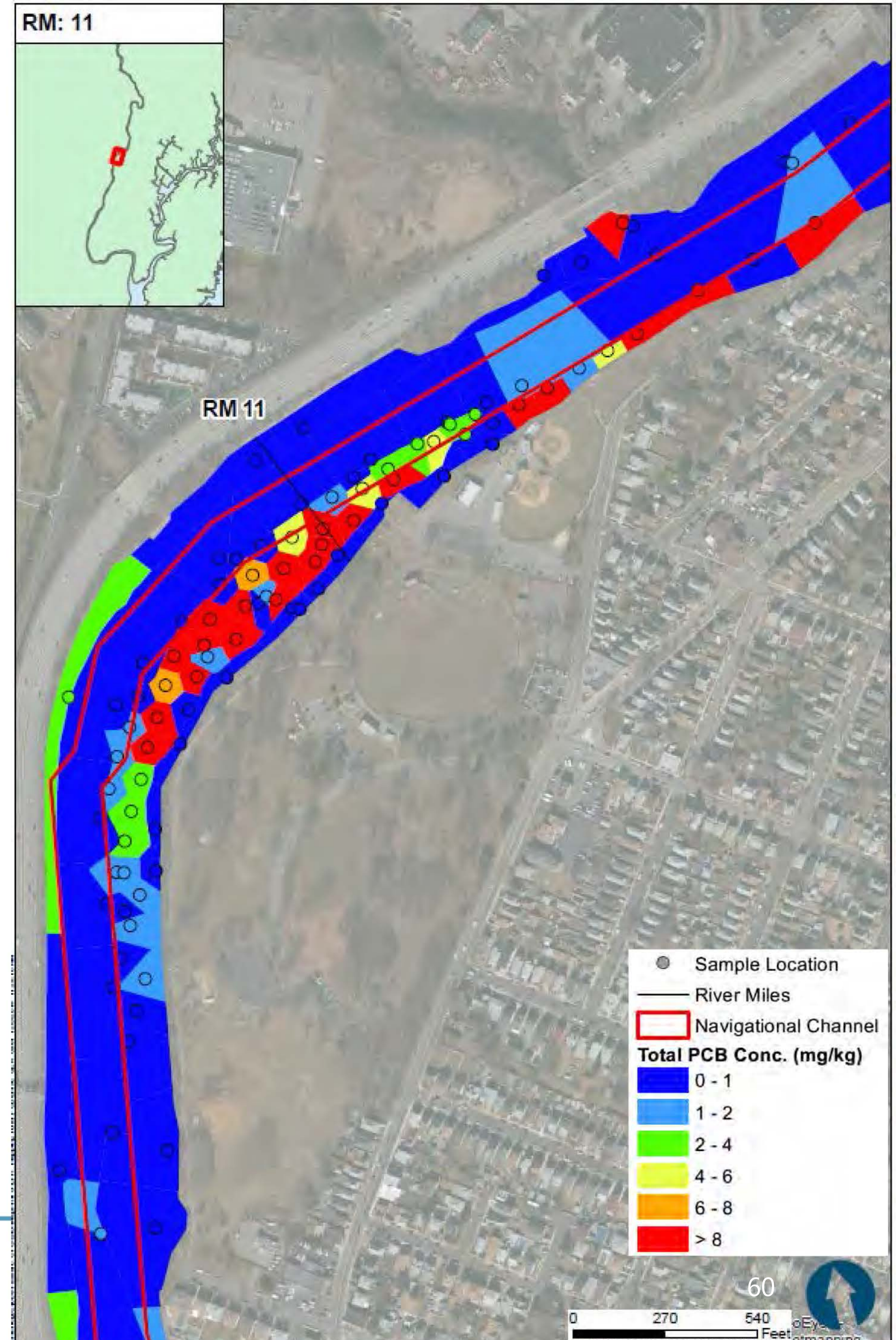
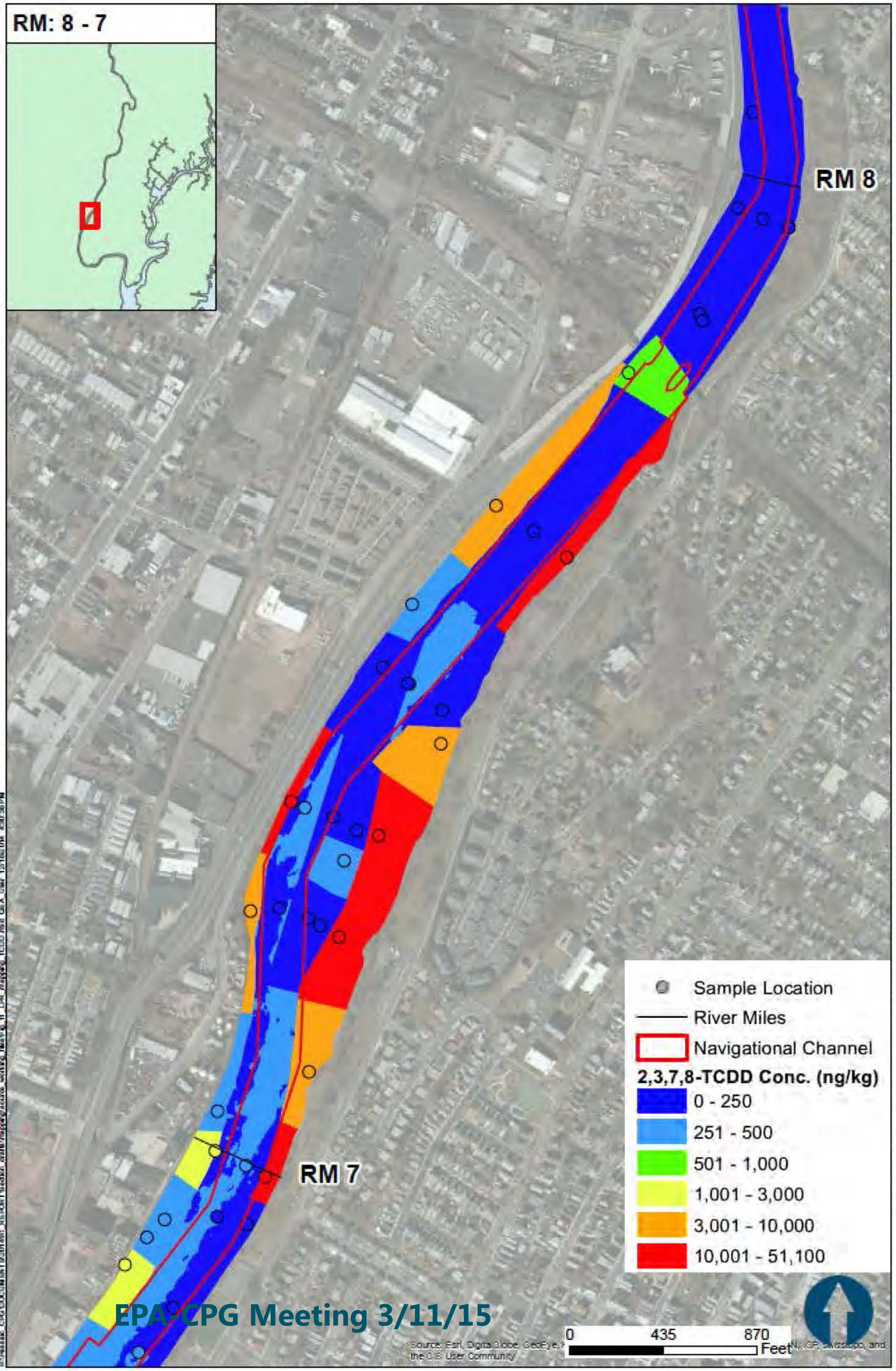
# Higher 2,3,7,8-TCDD Concentrations in Discrete Pockets



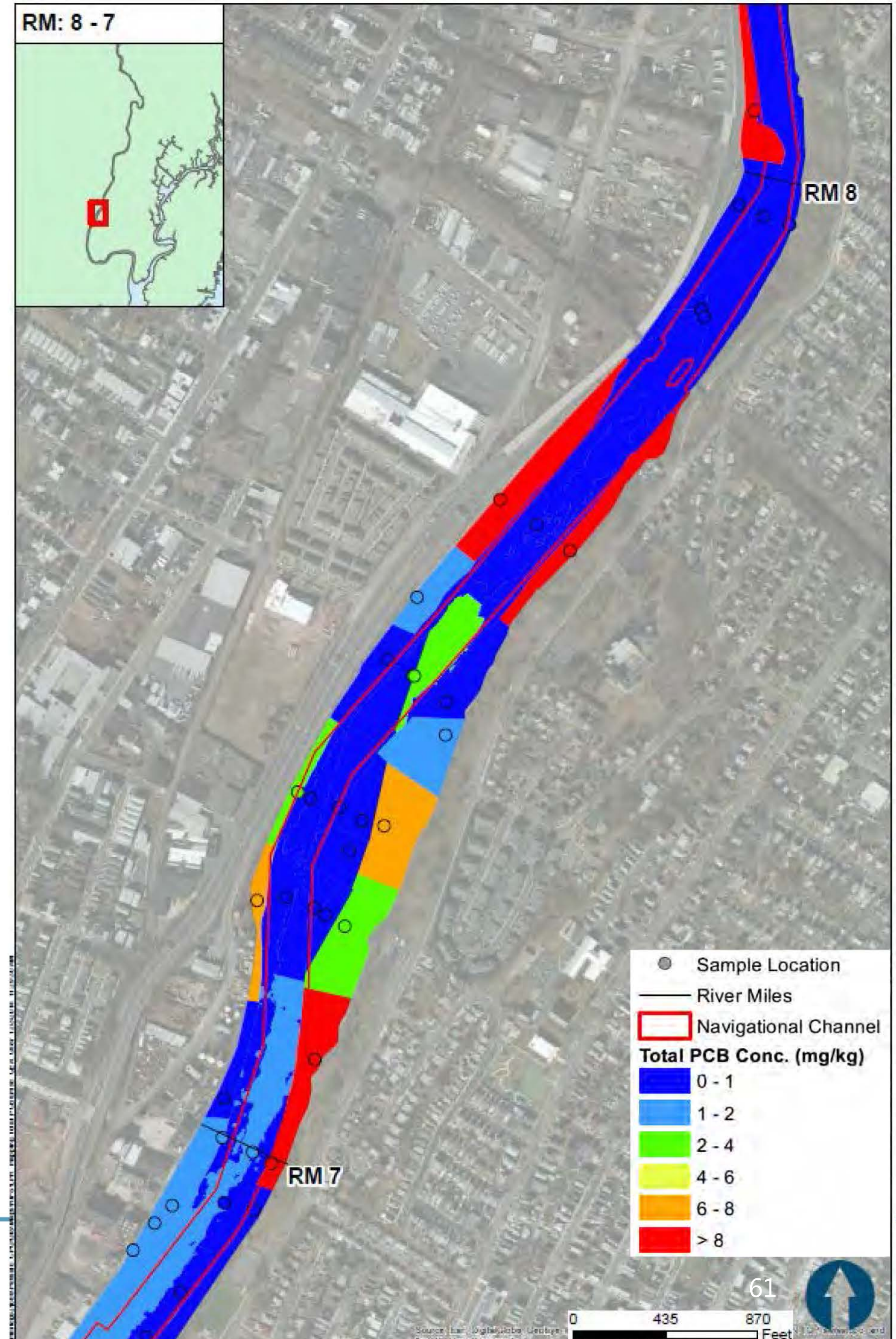
# Comparison of 2,3,7,8-TCDD and PCB Mapping


RM: 11
RM 11
Sample Location
River Miles
Navigational Channel
2,3,7,8-TCDD Conc. (ng/kg)
0 - 250
251 - 500
501 - 1,000
1,001 - 3,000
3,001 - 10,000
10,001 - 51,100
0 270 540
Feet

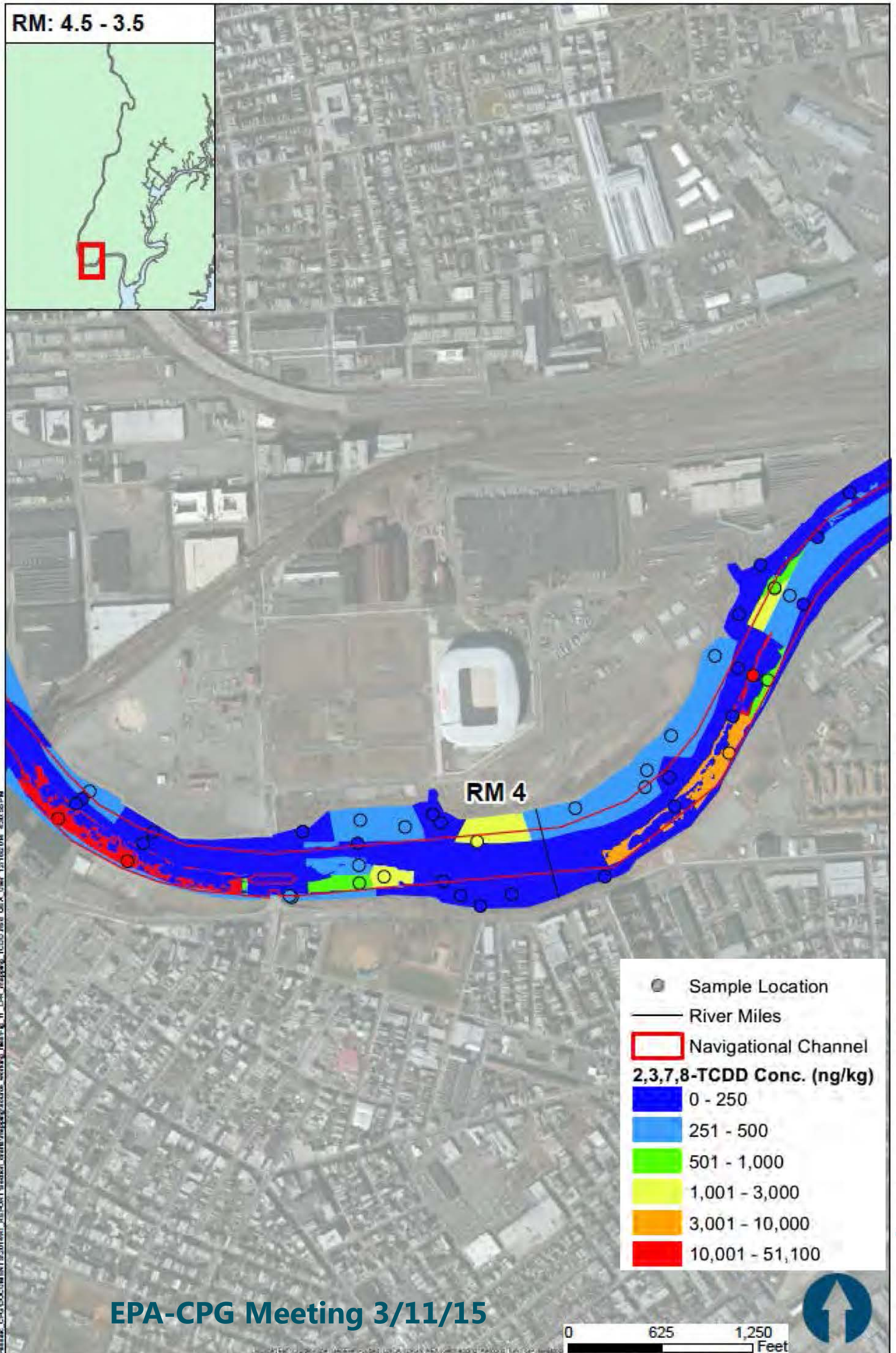

RM: 11
RM 11
Sample Location
River Miles
Navigational Channel
Total PCB Conc. (mg/kg)
0 - 1
1 - 2
2 - 4
4 - 6
6 - 8
> 8
0 270 540
Feet



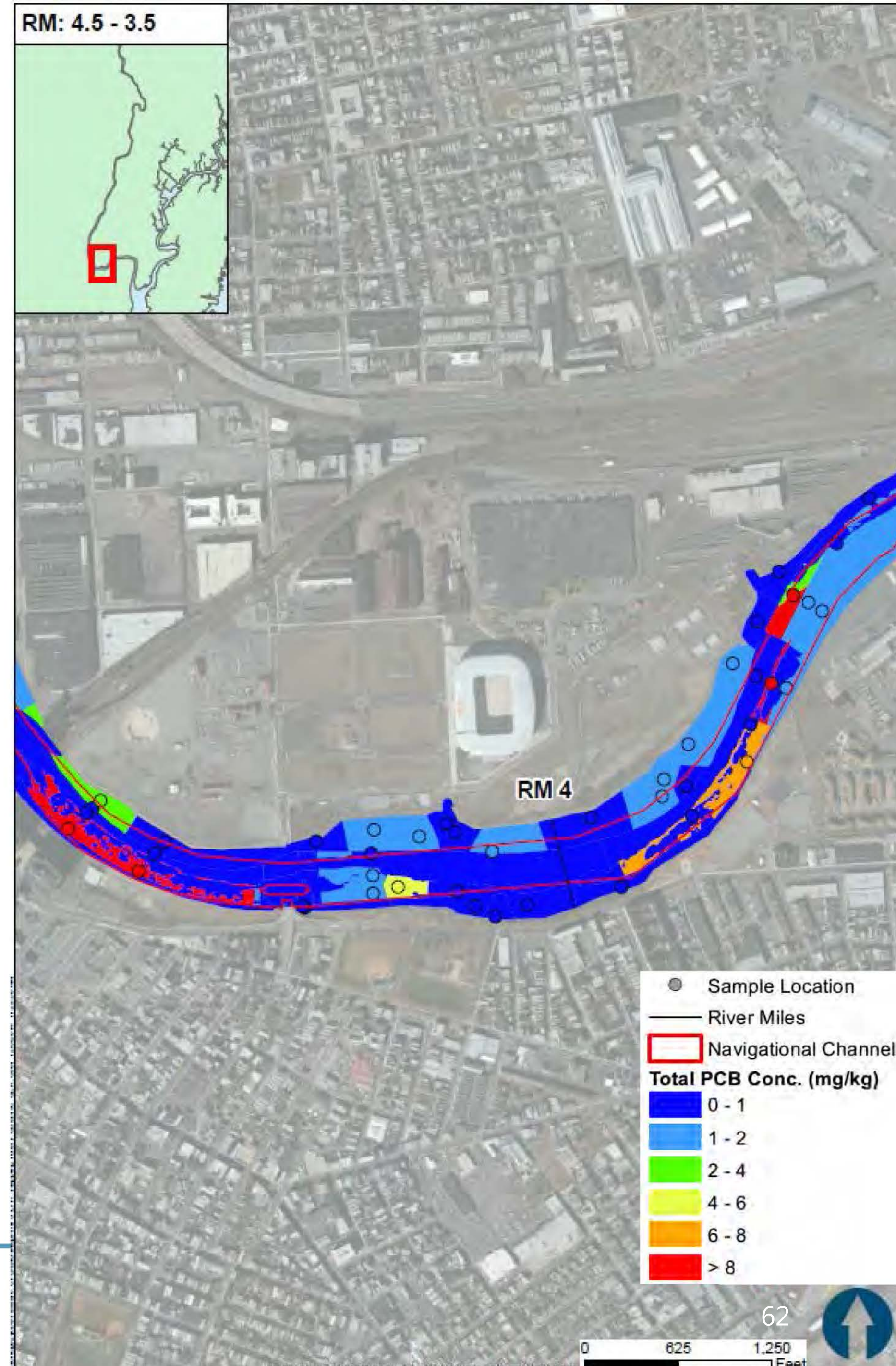
RM: 8 - 7
RM 8
RM 7
Sample Location
River Miles
Navigational Channel
2,3,7,8-TCDD Conc. (ng/kg)
0 - 250
251 - 500
501 - 1,000
1,001 - 3,000
3,001 - 10,000
10,001 - 51,100
0
435
870
Feet

RM: 8 - 7
RM 8
RM 7
Sample Location
River Miles
Navigational Channel
Total PCB Conc. (mg/kg)
0 - 1
1 - 2
2 - 4
4 - 6
6 - 8
> 8
0
435
870
Feet



RM: 4.5 - 3.5
RM 4
Sample Location
River Miles
Navigational Channel
2,3,7,8-TCDD Conc. (ng/kg)
0 - 250
251 - 500
501 - 1,000
1,001 - 3,000
3,001 - 10,000
10,001 - 51,100
0
625
1,250
Feet

RM: 4.5 - 3.5
RM 4
Sample Location
River Miles
Navigational Channel
Total PCB Conc. (mg/kg)
0 - 1
1 - 2
2 - 4
4 - 6
6 - 8
> 8
0
625
1,250
Feet

# Conclusions

- Organized patterns support mapping of concentrations based on interpolation among the point measurements
  - Areas of high and low sediment contamination are identifiable (though not the precise concentration) and related to
    - Long-term deposition patterns
    - Geomorphology
    - Recent erosion/deposition
  - Concentrations tend to be higher at locations where sediments deposited between 1949 and the mid-1960s are within the top 6 inches today
- Thiessen polygon interpolation has strong precedent and is favored because it preserves the distribution of concentrations in the river